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ABSTRACT

Designed to specifically assist science educators and science consultants in the preparation of teachers and for the development of curricula, this yearbook contains resources and ideas addressing the need for science, technology, society (S/T/S) in school science programs. Eleven papers are organized into three thematic sections. Part one focuses on some foundational aspects of S/T/S and includes: a rationale for S/T/S; an examination of its roots; and an analysis of secondary science teaching practices with implications for S/T/S implementation. The second section presents alternative models for approaching the problem of preparing teachers for S/T/S science teaching and discusses reasons for revisions in science teacher education; certification redirections; a course in the epistemology and sociology of science; an inservice program; and interdisciplinary S/T/S teaching approaches. The final section examines models and resources for science educators and supervisors to use in assisting schools to develop, adopt, and/or implement S/T/S curricula. (ML)

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1985 AETS Yearbook

SCIENCE, TECHNOLOGY AND SOCIETY: RESOURCES FOR SCIENCE EDUCATORS

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Forward

The SMEAC Information Reference Center is pleased to continue cooperating with the Association for the Education of Teachers in Science in producing these Yearbooks.

We invite your comments and suggestions on this series.

Stanley L. Helgeson
Patricia E. Blosser

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PREFACE

The clamor for change in education has been a persistent concern since the early 1980's. Various commissions, committees and legislatures have met to discuss the issues. Science has been recognized as one of the subject areas needing more careful attention by schools, teachers and students. Many educational leaders have questioned the conventional wisdom expressed in the recommendations, reports and laws resulting from these concerns. It seems clear that providing science students more of the same content taught at a higher level will not prepare citizens who will be able to cope with and attenuate the pressures of a society in which their personal lives, careers and daily existence are increasingly dominated by the complex interactions of science and technology.

Leaders in science education have emphasized that the redirection of K-12 science must include a focus on the interactions among science, technology, and society (S/T/S). These ideas have been omitted from the materials that are in common use in K-12 science classrooms and they have been absent from the preservice and inservice science teacher education programs in most colleges and universities.

While numerous journal articles and some committee reports have recently been written about the need for S/T/S in the school science programs, little attention has been paid to the needs of science educators as they prepare teachers and assist schools. This volume points out these needs to science teacher educators and provides some resources and ideas to meet these needs.

The book is divided into three parts: foundations for the S/T/S frame of reference; models for preparing teachers for S/T/S; and implementation of S/T/S: resources for change. It is intended to be a compilation of resources and ideas for science teacher educators and science consultants as they prepare teachers, develop curriculum and assist schools in the adoption and implementation process.

PART I FOUNDATIONS FOR THE S/T/S FRAME OF REFERENCE

This section presents some foundational aspects for S/T/S in science education. It includes Bybee's rationale and justification for the S/T/S emphases; an examination of the roots of S/T/S in the history and philosophy of science by Duschl; and Gallagher's recognition of some realities of current science teacher practices and how those may affect the actual use of S/T/S.

PART II MODELS FOR PREPARING SCIENCE TEACHERS FOR S/T/S

The second part of the book presents alternative models for approaching the problem of preparing teachers for S/T/S science teaching. Kuerbis' chapter summarizes the several aspects of the problem and presents a rationale for change; Yager focuses on certification programs and suggests specific redirection; Aikenhead describes a single course approach he is currently using; and Spector examines methods, issues, and programs which might be used in inservice activities and master's degree S/T/S teacher preparation efforts. Hickman emphasizes that S/T/S teacher preparation can best be accomplished via an interdisciplinary approach and goes on to describe the role of the Colorado Alliance for Science in forging a partnership among universities, schools, and industries in preparing teachers for interdisciplinary S/T/S teaching.

PART III IMPLEMENTATION OF S/T/S: RESOURCES FOR CHANGE

The final section examines models and resources for science educators and supervisors to use as they assist schools in development, adoption and/or implementation of S/T/S curricula. Ellis recounts the BSCS experience and thrust in S/T/S curriculum development; Penick identifies and describes S/T/S programs that are currently in existence; and James and Horn point up the need to go beyond the proclamation of crisis toward the development of products, and a focus on the process of change.

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The chapter authors cooperated in a marvelous way in responding to my requests. Turn around time has been short and numerous telephone calls have substituted for hard copy communications. Most of all I want to acknowledge the quality of their efforts in bringing to the attention of our peers the resources, ideas, and projects they have generated in an effort to stimulate a greater emphasis on S/T/S in science programs.

A special acknowledgement is made to Marc Horn who has exerted much effort in the editorial process as well as in assisting in the preparation of the final chapter. Gratitute is extended to the Department of Educational Corriculum and Instruction, Texas A & M University for supporting this project in a variety of ways, including Marc Horn's time and mine.

Finally, I would like to recognize my family for their support and patience during this process, and especially to thank my wife, Dorothy, for her dedicated effort in the typing of the final manuscript.

Robert K. James, Editor

PART I

FOUNDATIONS FOR THE S/T/S FRAME OF REFERENCE

CHAPTER 1

SCIENCE - TECHNOLOGY - SOCIETY: AN ESSENTIAL THEME FOR SCIENCE EDUCATION

Rodger W. Bybee

INTRODUCTION

As we approach the year 2000 most people living in industrial societies are enjoying a quality of life unprecedented in history. Children survive traumas and diseases of premature birth and early childhood that would have been fatal a few decades ago. The elderly live longer and enjoy the benefits of health and well being. Personal living is more convenient and pleasant, our natural and human environments enrich our lives. Science and technology are largely responsible for these and many other benefits that enhance life and living.

The year 2000 is also growing near for three quarters of the world's population not living in industrialized societies. These people still await the benefits of science and technology that promise to ease their pain, feed their hungry, and reduce their burdens of labor. Science and technology could also contribute to improving their quality of life. But as yet the promises have not come to fruition.

Until recently, one could not have written these paragraphs about the benefits and promises of science and technology. The degree to which science and technology influence our lives and transform societies is only now being realized. For two centuries science and technology have increasingly shaped the character of American society. Throughout most of history the interaction and significance among science, technology, and society went unrecognized. During this time, however, the interaction continually changed. Citizens became aware of the promises of science and technology. Government became involved in the support of research and development. Science evolved from "little" to "big." Technology also became larger and more sophisticated. With little fanfare, science and technology slowly moved to center stage in society.

A paradox has also recently emerged. Scientific advances and technological innovation have contributed to both social progress and cultural problems. And, many of the same citizens who became aware of the scientific and technological promises also became aware of the problems. While science and technology moved to center stage, the stage was also being set for a conflict between science, technology and democratic participation. How is the conflict to be resolved? Enter here the increasing role of public policy debates.

In the late 1980s, many critical decisions related to the role of science and technology will have to be made by the nation. The decisions will be made relative to many local and regional issues - land use, acid rain, atmospheric conditions, carbon dioxide, toxic waste dumps, energy shortages, preservation of endangered species, and water resources to name only a few examples. Decisions will also be made concerning budgets for research and development, and the role of public and private institutions' support of science and technology. Who should make decisions about problems? Research? Development? Applications? The federal government? Scientists? Citizens? On what basis should these decisions be made? Economic? Moral? Contributions to the public health and social welfare of the nation? Knowledge for knowledge sake? Fulfilling the needs of humanity? General recognition of these questions has brought about problems concerning the public's ability to participate in decision-making and policy development within American society.

Several factors underlie the general problems of public participation in science and technology related issues. Democratic participation is more widespread, but the groups often have a single issue orientation. Public interest in participation has increased, but the public often lacks the ways and means to influence decisions. There has been greater reliance on experts to explain complex issues related to science and technology, but the experts often do not agree and, in addition, many have ventured beyond facts into the domain of ethics and values. The media have increased public awareness of science and technology related issues, but public understanding of the concepts, values, and processes involved in contemporary issues is lacking.

These and other factors converge on the need to identify appropriate means of directing science and technology while simultaneously maintaining the independence of scientists and engineers to pursue their research and development and the freedom of the public to participate in decisions and policies affecting their lives. With time, this fundamental tension between scientific independence and social control will only increase. A careful balance must be reached in the coming years. Achieving a balance between the values of science and society suggests the need for citizens to be well informed concerning social issues and the facts and values related to the costs, benefits and consequences related to decisions made about science, technology, and society (S/T/S). There is need for a new scientific and technologic literacy. Recognizing and responding to this need means there will be a fundamental redesigning of science education.

Thus far, the author has tried to present a general introduction to more specific themes and discussions of the next sections of this chapter and the subsequent chapters of this yearbook. First, there is a science education context for later discussion. A second section is on the historical contributions of science and technology to society. Next is a section describing some significant science-related social changes that have occurred since the Sputnik-inspired curriculum reform era. Finally, there is a section outlining the contemporary challenges of science and technology in society.

A SCIENCE EDUCATION PERSPECTIVE

The date October 4, 1957, was historic in science education. The Soviet Union launched Sputnik on that day and a curriculum reform movement that was already in progress was propelled forward with both spiritual and fiscal support. Twenty-five years later, October 1982, was an occasion to ask about the condition of science education. Upon examination, the public found that science education was in a state of crisis.

Questions about the curriculum reform movement were immediate and pointed. Did the reform movement of the 1960s and 1970s fail? If the new science programs were a success, then why is there a crisis? What was wrong with the new science programs? All of these are legitimate questions and should be answered.

First of all, it can be said that the initial goals were achieved. Thousands of scientists and engineers were brought into the work force. A national goal and appropriate technology landed men on the Moon and returned them safely to Earth. In the process, science and mathematics programs and teachers' backgrounds were updated.

Second, why is there a crisis? The answer can be stated directly - the goals for past social challenges are not adequate for present social challenges. The "golden age" of science education has passed. Many of the "new" science programs soon will be 25 years old! Now is the time to develop a perspective suitable for the late 1980s and beyond.

Third, there was at least one mistake made in the 1960s that is related to the present situation in science education. An implicit question to the reform movement was - "What does a student need to know and do in order to be a scientist or engineer?" The answer - the student should understand the structure of science disciplines and processes of scientific investigation. With these answers, we developed programs that appealed primarily to students bound for colleges and universities and eventually for careers in research and development. The mistake was to purge programs of any emphasis on a citizen's use or understanding of science and technology. Teachers continued to claim they were "preparing students for life," but failed to characterize it as the life of a scientist or engineer. This is not an argument about what was done, or what should have been done, if the goal was preparation for careers in science and engineering. This goal was, and continues to be, inappropriate for the majority of our students and inconsistent with the historical goals of public education -- namely citizenship. The new S/T/S thrust in science education is toward what was not done in the 1960s and 1970s, and what must be done in the 1980s and beyond. We should provide an education appropriate to needs and concerns of students as future citizens which will enable them to live, work and participate in a society which is increasingly scientific and technological. There is a need to reinstate personal and societal goals that were eliminated in the 1950s and 1960s. Additionally, we need to update science education to include changes in S/T/S that have occurred in the past 25 years. Some of this discussion has clear implications for science teacher education.

Before continuing, it is worth making explicit an assumption about science and technology education. Science and technology education is a subsystem of the education system. As such, the goals of science and technology education, like education or any social institution, must simultaneously facilitate personal development and achieve the purposes of society within the parameters of the institution. We must be aware of the general aims of education and the specific goals of science and technology education. In clarifying this point, it may be helpful to consider the analogy of basing diagnoses of disease of internal organs on external symptoms. For example, pains in the arm and neck may or may not be symptomatic of heart attack. Hence, an initial diagnosis must be carefully considered and corroborated by evidence which extends beyond initial symptoms. This analogy helps us to understand a portion of the current crises in science education in relation to the S/T/S theme.

Thus, one must begin to understand the related nature and meaning of different dimensions of the science education crisis. The type of problems commonly discussed are the practical, everyday science teaching matters of budgets, materials, supplies and "how to" lessons to use immediately. But, if remedies are provided for these practical problems, will the crisis go away? No. Why? Because the practical problems are only symptoms of larger, more integrated problems.

One also hears about problems which pertain to educational policy. How to teach mainstreamed students, teacher evaluation, the voucher system, and so on. Will these remedy the ills of science and technology education? Probably not. One must look further.

What about programs? Curriculum materials are outdated. New textbooks have not been purchased. In general there is need for improvement of teacher education programs. So, is this the answer? It seems unlikely.

All of the factors mentioned -- practical, policies, and programs need changing and improvement. While none are the answer, they are all part of a response to the crisis.

The author's position is that we must redefine the purposes of science education. That is, establish new goals and then redesign programs, rethink policies, and reformulate practices. And, all of this includes the education of science teachers. The reason for advocating the S/T/S as central to the purposes of science education is that we come to an understanding of the need for change (and hence move beyond the crisis). Very importantly, it provides a direction for change.

This discussion and brief analysis of science and technology in part serves as a context for the following discussions of S/T/S. It also establishes the position that this paper is also a rationale and justification for the S/T/S theme in teacher education.

CONTRIBUTIONS OF SCIENCE AND TECHNOLOGY TO SOCIETY

Bertrand Russell's 1952 book The Impact of Science on Society stands as a particularly cogent early analysis of the interactions among science, technology, and society. Russell suggests that the effects of science have taken several different forms. Science has had intellectual effects, e.g., a greater stress on empirical observations and the scientific method;

technological effects, e.g., in industry and war, work is more efficient and nations are more powerful; social organizational effects, e.g., control is more centralized and experts can gain more power; and philosophical effects, e.g., a new pragmatic philosophy has developed based on utility rather than on truth which ultimately could have disastrous consequences for society. The next paragraphs describe some of the details relative to these contributions.

The first influence science had on society was intellectual. Stress on empirical observations and use of scientific methods have served to dispel such things as beliefs in witchcraft, demons, and so on. The result has been a mechanistic world view with the following ingredients:

1. Observation versus authority. The resolution of matters concerning the natural world can be ascertained through observation and not through appeal to authorities such as Aristotle.

2. The physical world conforms to natural laws. There is no need to envoke external forces, e.g., dieties, to explain the movement of objects. The causes for certain effects in the natural world are to be found in the natural world itself. We have Galileo and Newton to thank for this world view.

3. Dethronement of "purpose". While there is human purpose, there is not room for purpose in scientific explanation. Darwin's theory of evolution through natural selection is a good example of the scientific dethronement of purpose as an explanation.

4. Human place in the world. There are two aspects to this intellectual influence. One was the humbling of human perceptions about their place in the universe. Kepler and Copernicus contributed to this changed world view. On the other hand, humans gained a degree of power to cause changes. Prior to the scientific world view, prayer and humility were thought to influence change. This view was replaced with one that encouraged acquiring knowledge and understanding natural laws. The power of the latter was found to be greater and more reliable.

Technology has a long history of important contributions to society. Russell uses two discoveries of the late Middle Ages -- gunpowder and the mariner's compass -- as critical in the interaction between technology and society. Gunpowder gave military power to governments. The long development and escalation of weapons of war have continued to this day. The compass opened the age of discovery. After these important technologies there was a long period with relatively few applications of knowledge to more efficient ways of doing things. Most people are familiar with other major technological contributions such as the cotton gin, electricity, and the internal combustion engine.

Invention of the telegraph had an influence on social organizations. Messages could travel faster than people; subsequently, governments had more power to enforce law and order. And power could be located in a central position in governmental and private organizations. This observation is true of many technologies. Power is centralized in a few, and the power is greater than it had been historically.

There is a very important point about the contributions of technology to society. Technology increases the interactions and interdependence among social systems. In a word, societies become "organic". Russell discusses this point:

> The most obvious and inescapable effect of scientific technique is that it makes society more organic, in the sense of increasing the interdependence of its various parts. In the sphere of production, this has two forms. There is first the very intimate interconnection of individuals engaged in a common enterprise, e.g., in a single factory; and secondly there is the relation, less intimate but still essential, between one enterprise and another. Each of these becomes more important with every advance in scientific technique. (Russell, 1952, p. 42).

Russell is correct on this point. Witness the more "organic" nature of society as new techniques for information dissemination have developed. There is an additional point worth noting. Since Russell wrote these essays (since 1950), the society has extended to a global community that is interdependent in large measure due to technology. The size and power of social organizations have grown to international, in fact global, dimensions.

In a later chapter on "Democracy and Scientific Technique", Russell returns to this "organic" theme and makes a point related to public participation, a point that is common to discussions of S/T/S themes in education. Here is Russell's view.

> The main point is this: Scientific technique, by making society more organic, increases the extent to which an individual is a cog; if this is not to be an evil, ways must be found of preventing him from being a mere cog. This means that initiative must be preserved in spite of organization. But most initiative will be what may be called in a large sense 'political', that is to say, it will consist of advice as to what some organization should do. And if there is to be opportunity for this sort of initiative, organizations must as far as possible be governed democratically. Not only so, but the federal principle must be carried so far that every energetic person can hope to influence the government of some social group of which he is a member. (Russell, 1952, p. 72).

The message to educators seems clear. The means to preserving personal initiative is through educating people about the ways and means of participating in the democratic process. This seems especially applicable in the context of science and technology related social issues. This point seems even more relevant today than in the 1950s when Russell wrote his essay.

Russell's fourth contribution about philosophy argued strongly that John Dewey's pragmatism ultimately would not be beneficial. Russell maintained that substituting the value of utility for truth was inappropriate.

Additionally, the pragmatic philosophy shifts the balance of science and technology toward technology, due to the emphasis on application and utility (Russell used the phrase "engineer's philosophy" to describe pragmatism). No effort will be made to resolve the philosophical point here. Suffice it to note that different philosophies do prevail and do influence the public's perceptions about science and technology in society.

Upon a re-reading of The Impact of Science on Society for this AETS Yearbook chapter, the author was struck by the degree to which Russell identified, in the early 1950s, many contemporary issues that will be discussed in the next two sections. In a chapter entitled "Can a Scientific Society be Stable?", he concludes with a set of conditions that a scientific society must fulfill if it is to be stable. These are mentioned here because they are ideal precursors to discussions in the next section on "Challenges of Science and Technology in Society." Conditions put forth by Russell included not using soil and raw materials faster than scientific and technological progress can replace the loss. Population growth must be controlled at levels lower than the rate of food production. Finally, he suggests the need for a general diffusion of prosperity, a single world government, provisions for individual initiative in work and play, and a diffusion of power compatible with the maintenance of political and economic frameworks.

All through this discussion of the contributions of science and technology to society, we have seen tension between the potential goods and possible evils. From gunpowder to atomic weapons, there is simultaneously security and insecurity. In the centralization of power and authority, there is efficiency and loss of personal freedom. These issues are not unlike those we confront today as a society. One point is different from the Middle Ages, or even the 1950s when Russell wrote. Science and technology are much more influential. They are powerful forces for social transformation and need for public understanding -- scientific and technological literacy -- is even more urgent.

A SOCIAL PERSPECTIVE

Significant social changes have occurred since Bertrand Russell wrote The Impact of Science on Society and Sputnik was launched. Examples particularly important to science and technology education will be used to highlight some of the fundamental social changes that have occurred in the past two and a half decades.

Silent Spring was published in 1962. This powerful book directed the world's attention to the detrimental effect of chemicals. Rachel Carson warned that the indiscriminate use of chemicals could "linger in the soil," "slow the leaping of fish," and "still the song of the birds". If society continued contaminating the environment, then one day society would experience a silent spring. Rachel Carson did go beyond the available evidence. She was criticized for the book's alarming message. But, the book became a symbolic figure and the environmental movement was born. Rachel Carson's basic conviction was stated in a Congressional hearing when she urged that this generation must come to terms with nature. For the remaining years of the decade, society began coming to terms with our effect on the environment. We witnessed the establishment of many public policies: in 1965 Congress passed the Clean Air Act (and subsequently in 1970 and 1975) and the Solid Waste Disposal Act. In 1966 the Species Conservation Act was passed, and in 1969 the National Environmental Policy Act was passed.

In 1969 the world witnessed the achievement of the greatest technological challenge in human history. Men were landed on the moon and returned safely to Earth. Clearly, this was a decade that closed with scientific success. But, other societal issues had occurred during this period. Protests began against a war in Vietnam. And in the United States, urban problems generated social concerns. Comparisons of money spent on space programs versus poverty-related problems were reported and debated. Technological advances were identified both with space exploration and the power of destruction in war. The advantages of industrial growth were weighed against the disadvantages of pollution. By the end of the 1960s, some of the science-related issues that were so important at the beginning of the decade were achieved, resolved, or forgotten, and entirely new problems had emerged. But the reader should note that many themes identified in Russell's analysis of science and society were clearly evident.

The 1970s brought society the first realization that past ideas and values about growth were being questioned. High technology was challenged in the specific form of the supersonic transport (SST). After a long Congressional battle, support for the SST was terminated. In 1972 the public heard that we needed to recognize The Limits to Growth (Meadows and Meadows, 1972) and we had Only One Earth (Ward and Dubos, 1972). In the event that people had missed the messages of these books, the Organization of Petroleum Exporting Countries (OPEC) made it explicitly clear through the oil embargo of 1973-74. The embargo brought the issue of energy to the public's attention and it has been there ever since.

During the decade 1970-80, Congress passed a number of bills related to the environment, including the Water Pollution Control Act (1972) the Endangered Species Act (1973), the Toxic Substances Control Act (1976), and the Clean Air and Clean Water Acts (1977). But, as the decade drew to a close, the Three Mile Island incident further underscored the impact of technology on society and brought the themes of science, technology, and society to the public consciousness. This incident symbolizes the ambivalence between society and science that had developed for two decades. There was, simultaneously, the hope for cheap energy and the disillusionment with technology; the need for energy and the questioning of nuclear power; the possibility of unlimited energy and profound vulnerability based on science and technology.

Many themes of the 1960s and 1970s were substantiated in the 1980s and extended from local or national levels to global concerns. The Global 2000 Report to the President: Entering the Twenty-First Century serves as an example. Here is a summary of the major findings and conclusions:

> If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.
>
> For hundreds of millions of the desperately poor, the outlook for food and other necessities of life will be no better. For many it will be worse. Barring revolutional advances in technology, life for most people on earth will be more precarious in 2000 than it is now - unless the nations of the world act decisively to alter current trends. (Barney, 1980, p. 1).

In the 25 years since Sputnik and 35 years since Russell's book, there has developed an environmental movement, a growing concern about the role of science and technology in society, a recognition that the rate and direction of social growth must change, and a realization of the global dimensions of problems and the interdependence of human beings with each other and their environment.

CONTEMPORARY CHALLENGES OF SCIENCE AND TECHNOLOGY IN SOCIETY

This section begins with a brief discussion of science and technology as they relate to one important aspect of contemporary society -- economic growth. Perhaps this discussion could have been in the section on contributions, but presently it will become evident why it is here in the section on challenges.

Economic growth results from the combination of labor, capital, and land (natural resources) for the production of social goods and services. Science and technology contribute to economic growth in several different ways. There is the creation of new products and services with the resulting expansion of consumer choice. Science and technology also contribute to more efficient (less expensive) production of goods and services. And, finally, the resources used for economic growth are extended through better extraction and processing and through development of synthetic substitutes that can replace natural resources which are too expensive and/or not available. In the example of economic growth, one can see the symbiotic relationship that has been established within science, technology, and society. Support for research and development contributes to economic progress which, in turn, provides more support for scientific investigation and technological innovation.

While this makes sense, many people know that all is not well in industrialized societies. There are many characteristics of industrial societies such as advanced technology, complex social organizations, and rapid social transformation. However, it is worth directing our attention to the characteristic mentioned above, namely a commitment to continued economic growth. In Problems of an Industrial Society (1981), William Faunce suggests that we are witnessing problems *of* industrial societies as opposed to problems in an industrial society. That is, there are problems unique to and inherent in the social structure and function of industrial societies. There are some problems common to all societies -- crime and poverty, for example. But there are some problems only found in contemporary industrial societies. What are these problems? And, more importantly, how are they related to science and technology? Here is William Faunces' list of problems: resource depletion, environmental degradation, individual alienation, and threats to personal freedom. Two of these problems, resource depletion and environmental degradation, are very closely related to science and technology. Alienation and loss of freedom are indirectly related through large bureaucratic organization, mechanization, and lack of participation in public policy. The author is more concerned about resources and the environment because they pose a more fundamental threat to long term social stability. Recommendations for a S/T/S emphasis in education programs includes public participation which, at least partially, recognizes the problems of alienation and loss of freedom.

The reader should be reminded that the Industrial Revolution was based on the use of fossil fuels to run machines. Very importantly, these fossil fuels were perceived to be an unlimited resource that was cheap. Other natural resources such as various metals were also basic to the industrialization of society. Along with perceptions of unlimited resources, there was an apparently unlimited environment for waste disposal. With these perceptions, the advances of science and applications of technology, the economy prospered. But now we realize that resources and environments are finite. These are the related challenges for science and technology.

In Science and Technology: Promises and Dangers in the Eighties (Watts, 1980), it outlines four challenges to future expectations for science and technology. The first two are external to society. The primary challenge is limited resources, e.g., physical, social, and economic restraints on growth. The second external challenge is from a changing world order, e.g., emergence of Third World powers and interdependence of nations. There are two challenges from within society. One is public participation in science policy making, e.g., institutional forms and legislation. And, second, an understanding of the increasing complexity of the science and society relationship, e.g., scientific and technologic literacy. These challenges will be discussed in the following sections.

Limited resources are seen by many as the most critical challenge because resources essential to traditional economic growth are diminishing. As resources continue to decrease, prices of goods and services will increase, and science and technology will strain to extend the limited resources through new discoveries. But there are inevitably going to be diminishing returns. And, as noted earlier, the symbiotic relationship between science, technology, and society could be broken due to decreased financial support on the one hand, and fewer innovations to spur economic growth on the other.

There are other social concerns such as taxpayer rebellion and the rising cost of government that are outside the scientific and technologic enterprise, but do affect it. There are, however, constraints directly related to science and technology. The cost of doing research has increased enormously in recent decades. And, when you consider that physics and chemistry are no longer the only major research areas (there are also the life, earth, and social sciences), then it is fairly easy to see that fewer dollars are being spread further, to cover increased costs. And, all of this with higher expectations for economic returns for investments in research and development.

The paradox in this situation is that investments in science and technology are critical if society is to move beyond the present situation. There are much needed resources to be found within the community of scientists and engineers that can help with natural resource problems, policy options, and economic and political choices.

Without much notice, we have become a global community. This constitutes the second challenge. After World War II, the United States was a world leader in science and technology. In the decades since the war, Western Europe and Japan have also become world leaders. In addition to this, Third World countries have emerged with coalitions of power that influence the economies of other more developed countries. The 1973 OPEC oil embargo serves as a good example for this challenge (and the one of limited resources).

After World War II, there were increased numbers of countries with the basic skills for labor. The result has been equal abilities to manufacture products at less cost. The result has been a shift of production of goods and serices to other countries. The balance of foreign trade shifted as the U.S. bought more from and sold less to other countries. To this scenario one can add the development of multi-national corporations and the fact that they use natural and human resources from other countries, often Third World, and one can easily see the significance of the new world order.

How does this relate to science and technology? Several examples may make this relationship clear. Most scientists and engineers reside in developed countries and pursue the research and development priorities of their country. These priorities are seldom aligned with the real human needs of the developing world, and there is a problem with the transfer of technologies to the Third World. When technologies are transferred, they are often either inappropriate or maintained for an elite group. Other examples include development and sale of armaments and use of resources.

The complexity of science and technology and its powerful influence in society, combined with greater citizen participation in decisions and policy, forms the third challenge. Many decisions concerning science and technology, and issues related to science and technology, will have to be made in the late 1980s and in future decades. Who should make the decisions? On what basis should decisions be made? And, how should the decisions be made in a democratic society?

We have seen increased public participation in various forms which is significantly related to science and technology. Debates over the siting of nuclear power plants and recombinant DNA technology serve as two examples. The use of computers, issues of privacy, and problems involving risk and uncertainty have also brought public attention.

There is a tension growing between the necessary freedom of scientific enterprise and the requirement of public participation in a democratic society. This is related to the fourth challenge, scientific literacy. There is a strand of logic that connects the challenge to all of the others. An imperative in today's world is for individuals to understand the impact of the science and technologic enterprise on their personal lives in relation to important social issues. That is, they need to know about the history, philosophy, and social role of science and technology as well as the concepts, processes, and skills of science. Finally, there is need to introduce students to the ways and means of democratic participation in the context of science and technology related social issues (See, e.g., Bybee, 1984 and 1985).

CONCLUSION

The interaction and significance of science and technology in society is clear. That science and technology education is related to, but not reflective of, the needs of individuals and of society is cause for concern. Fortunately, there are authors in this yearbook who can formulate new directions for science education in general and science teacher education in particular. The thrust of this chapter has been toward an introduction to the S/T/S theme. As such, it is intended to serve as background and rationale for new perspectives on science teacher education.

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CHAPTER 2

DEVELOPING REFLECTIVE ATTRIBUTES IN SCIENCE TEACHERS THROUGH THE HISTORY OF SCIENCE

Richard A. Duschl

INTRODUCTION

It is becoming increasingly apparent, given recent advances in the scholarly fields of history and philosophy of science, that a strong content background for science teachers can no longer be limited to state-of-the art knowledge in a scientific discipline. If science teachers today wish to project themselves as individuals who are well rounded in scientific knowledge, then, in addition to the concepts, principles, theories, technologies, methods, and facts which science presently embraces, a teacher must also be conversant in the major themes in the history of modern science and in the major tenets of twentieth century philosophy of science.

Knowledge of content is certainly a necessary condition for the teaching of science. But in order to teach science as inquiry, a strategy still endorsed by prominent science educators (National Science Teachers Association, 1982; Welch, Klopfer, Aikenhead, and Robinson, 1981), it is not enough for teachers merely to be competent with the language and knowledge of science. To teach science as inquiry, to represent science as a discipline in which change occurs rationally, and to portray science as an activity which is grounded in sound judgment, teachers of science also must be knowledgeable of the processes and methods used by scientists to establish the content of science.

The rapid expansion of scientific knowledge and scientific influence in society has created a phenomenon which presents itself as a double-edged sword. On the one side, scientific research and the application of such research findings to the market place and to technology have created a standard of living and a set of investigative strategies in our society which are changing the very world in which we live. During this century alone, advances in communication and in medicine serve as concrete examples of the strides that have been made in science and technology and of the effects such efforts can have on society. However, the problem which faces society is that of keeping pace with the advances being made in science. When treated in isolation, modern science and technology can be meaningful only when including background knowledge of how science has arrived at a particular stage of development.

John Slaughter, former Director of the National Science Foundation, warned in his last year as director that one of the greatest problems we face as a society is the "growing chasm between a small scientific and technological elite and a citizenry uninformed, indeed ill informed, on issues with a science component" (National Academy of Science, 1982, p. 4). In defense of the ill informed, science is a difficult enterprise to understand. Changes in science not only occur with the status of knowledge claims but changes also take place with the methods, problems, evidence, and explanations used in science. Thus, a science education which focuses exclusively on teaching the prevailing knowledge claims of science devoid of references about how such knowledge came to exist is a science education which will contribute to, rather than detract from, the development of the chasm between the elite and the uninformed. A critical dilemma faces science and science education; how does science remain an objective rational enterprise if change is imminent? The disenchantment among people today with science and technology may be due more to society's confusion with the methods, criteria, and reasoning used by scientists than to society's ignorance of scientific facts and concepts. "The questions of why science today believes the peculiar things it does about the universe, and why it is willing to consider the alternatives it does, requires attention to the question of how science has come to think in those ways" (Shapere, 1984, p. 190).

Hence, what should also be a part of science curricula and science teacher education programs are factors which figure into the development of scientific knowledge for the explicit purpose of teaching about how science has come to think the way it does. To reach the goals set for science education, the intertwinings of basic science with applied science and technology need to be addressed as an object of science instruction. Such a goal requires the inclusion of topics in the history and philosophy of science in science teacher education programs.

In the planning and implementing of instructional decisions, it is clear that teachers exercise their beliefs, judgments, and attitudes about the nature of the subject matter. It is vitally important that teachers consider the changes in how historians and philosophers of science view the nature of scientific inquiry. In short, a revolution has occurred, creating a new image of science, and new interpretations for such time-honored scientific processes as observation and theory development. Teachers' awareness of such changes has implications for how they present scientific inquiry in their teaching (Robinson, 1969). How teachers of science are to be made aware of these new interpretations has implications for how science teachers are educated.

PURPOSE

The purposes of this paper are to: (1) discuss the implications that developments in history and philosophy of science have for science teacher education programs; and (2) to discuss how contemporary writings in the history and philosophy of science provide science teacher educators with a new lexicon of terms and library of information for inclusion in programs which prepare science teachers.

Research (Carey and Stauss, 1970) has shown that some individuals who complete undergraduate programs in science education do not develop proper views of the nature of science. Science education research also indicates that science teachers have attitudes and verbal behaviors which do not reflect the tentative nature of scientific knowledge (Kimball, 1969; Carey and Stauss, 1970: Tisher, 1971). The existence of such attitudes may, at least in part, explain why some students are reported to have authoritarian views of science (Horner and Rubba, 1978).

Norris (1984) considers the development of appropriate scientific attitudes among teachers as a crucial condition for presenting an accurate portrayal of the nature of scientific knowledge. Robinson (1969) expresses a similar point when he suggests that teachers' conceptions of science can influence their classroom behavior, word usage, laboratory design, and selection of instructional materials. Martin (1972) is more specific. He infers that teachers who are aware of the "new views of science" would be more likely to conduct laboratories which would have students subject theories to tests and possible refutation, and be less likely to use the laboratory to illustrate principles of science. Hence, while a research scientist may not necessarily need a background in historical and philosophical development in science in order to advance scientific knowledge, science educators most certainly should have a background with such developments in order to accurately portray the knowledge-seeking and knowledge-acquiring activities of the scientific enterprise. It is precisely in such activities that the intertwinings of science, technology, and society reside.

The implications for science teacher educators are that changes or modifications are needed in both preservice and inservice science education programs; changes which will help introduce individuals to new views about the nature of scientific inquiry, to new interpretations about the activities of science, and to heuristics for applying scientific reasoning in the design and implementation of curricula. The proposition is that the inclusion of topics in the history and philosophy of science as central components of programs of study would affect teachers' understanding and views of science and, in turn, have an impact on their representation of scientific inquiry in the classroom.

TOWARD A NEW IMAGE OF SCIENCE TEACHER EDUCATION

Applications of the history of science to science education are not new. During the fifties and early sixties, science curriculum materials were developed which did incorporate topics from the history of science. The work of Conant (1951, 1966), Klopfer and Watson (1957), Brush (1969), and Rutherford, Holton, and Watson (1970), was extensive. But, as Russell (1981) points out in a thorough analysis of issues surrounding the incorporation of topics in the history of science in science education, while historians of science involved in such projects focused on student understandings of the methods of science (Conant, 1966; Brush, 1976, 1974), the educational application of history of science made method less explicit and student attitudes and interest in science more explicit (Klopfer, 1969; and Rutherford et al., 1970).

In the conclusion of his paper, Russell (1981) issues a warning to science educators who might choose to use historical materials in science classes:

> It appears historical material does not insure improved understanding of science; due emphasis should be given to historical material to bring out specific characteristics of science. The two goals of accurate understanding of science and positive attitudes toward science are traditional and important,

> yet they should not be attempted indirectly or without consideration of competing influences (Russell, 1981, p. 64).

The competing influences Russell warns about are science textbooks and science teachers' behaviors. The issue for science teacher educators becomes, then, how prospective teachers of science can be trained to be reflective about how these competing influences affect students' understanding of science and of the characteristics of science. One potential strategy is to engage preservice science education majors in instructional activities which focus their attention on the internal history and development of theories, methods, technologies, and ideas within the scientific disciplines they plan to teach. An example is having students develop concept maps which depict the development of modern scientific theories. These have proven to be useful for helping teachers prioritize and organize scientific knowledge claims. Prospective teachers may then be better prepared to make the kind of considerations about the competing influences Russell addresses. It is to be hoped that teachers' decision making would begin to reflect consideration for the nature of the subject matter they teach.

Having prospective science teachers take courses in the history and philosophy of science is one potential strategy for developing science education majors who would consider the nature of the subject matter in the planning and implementation of instructional tasks. However, such courses are not offered at all institutions which train science teachers. Or, if such courses are offered, they may not address topics relevant to secondary level science curriculum, i.e., the history of modern science -- 1800 to the present. Consequently, strategies are needed for integrating the nature of subject matter activities into science teacher preparation programs.

To facilitate such integrations, an extensive guide for teaching the history of modern science has been prepared by Stephen Brush (1984) under a grant from the National Endowment for the humanities. The purpose of the guide is to assist persons who wish to discuss the history of modern science in their courses but have not had formal graduate training themselves. It is organized as a series of chapters covering the major developments in biology, anthropology, psychology, physics, geology, and astronomy since 1800. It is not a textbook or an essay on the history of science, but an outline of topics with detailed suggestions about materials that might be suitable for student reading and for instructor reference.

Adopting newer views of the nature of science can be useful for evaluating, interpreting and analyzing knowledge development in science and knowledge claims of science. For example, within a given discipline of science taught at the secondary level, which facts meet the criteria for being called novel facts? According to Lakatos (1970), scientific theories which predict novel facts have more explanatory power than rival theories which do not. Another example is, how have changes in the meaning of terms and in standards altered scientific practices? Shapere (1982) suggests that such changes are commonplace in science and can be followed in the scientific literature. Matching modes of explanation with certain disciplines, as Nagle (1961) and Kitts (1971) have done, helps explain the methodological procedures used by scientists in certain disciplines. These are just a few examples of concepts which the history of science and the new image of philosophy of science can provide. Having science teachers explore such concepts might just give them a truer sense of the nature of the scientific inquiry and of the relationships which have developed among science, society, and technology.

SUMMARY

Kyle (1980) emphasizes that there is a distinction between inquiry and scientific inquiry. Further, he argues that this distinction should be understood by high school students. For obvious reasons, the same demand should be made of teachers of science. However, a prerequisite that would enable a high school student to engage in productive scientific inquiry is to "acquire a broad and critical knowledge of the subject matter, which is acquired through the learning of basic competencies" (Kyle, 1980, p. 125). The need to maintain inquiry in the mainstream of science education is identified as a desired state by Project Synthesis (Welch, Klopfer, Aikenhead, and Robinson, 1981). Such a desired state recognizes that the role of the teacher is essential (Welch et al., 1981). A reasonable expectation of science teachers, as a prerequisite for teaching science as inquiry, is at least an appreciation for, if not an understanding of, the development of knowledge in the subject matter to be taught. Research reports of teacher attitudes and behaviors show that science teachers do not recognize or portray science accurately. In the preparation programs for science teachers reforms are needed which focus on this problem and demonstrate more appropriate outcomes. The present method of studying only about science in the academic science departments, as Carey and Stauss suggest, is a program which does not orient prospective teachers to a proper understanding about the nature of the subject matter they will one day teach.

Reconceptualizations of science teacher education programs which attempt to focus on science, technology and society must consider the developmental nature of science and technology and the historical interactions which have taken place among science, technology, and society if contemporary knowledge claims of science as taught in our classrooms are to be meaningful.

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CHAPTER 3

SECONDARY SCIENCE TEACHING PRACTICES WITH IMPLICATIONS FOR S/T/S IMPLEMENTATION

James Joseph Gallagher

INTRODUCTION

It seems safe to assume that the majority of secondary science teachers in U.S. schools are unprepared for teaching about technology and the societal consequences of science. Their education in university programs in science did not offer or encourage development of understanding of the applications and social implications of science. Moreover, few teachers have had opportunities or incentives to develop background related to these dimensions of knowledge.

These assertions were stated in an earlier paper along with some recommended changes in teacher education programs (Gallagher, 1984). The purpose of this paper is to enlarge on the earlier one in three ways. First, data will be presented from intensive studies of science teaching in secondary schools to give a picture of the "state-of-the-art" in school practice. Second, the implications of these data for teacher educators will be described. Third, some recommendations for teacher educators will be offered.

STATE-OF-THE-ART

During the past three years, the author has engaged in a series of ethnographic studies to gain a deeper understanding of the "culture" of secondary science teaching in public schools. These have included work in Michigan and in Western Australia. In May 1984, a two-year study of two school districts was begun under the sponsorship of the Michigan State University Institute for Research on Teaching with the aid of four graduate students also trained in ethnographic techniques. The purpose of this effort was to give greater depth to the understanding of secondary science teaching and the forces which influence it. What follows is a composite picture based on data, which are, as yet, incomplete. The data do not portray a particular school but offer some preliminary insights into the situation which exists in three U.S. school districts. Observations in Western Australia, like any cross-cultural experience, enriched our understanding of the character of U.S. secondary science teaching because of the contrasts and similarities which were observed.

The paragraphs which follow present observations about key issues which impinge on inclusion of S/T/S as part of secondary school science. Three school districts served as the basis of most observations. These included two buildings in a medium-sized city, two buildings in a middle-class suburban community, and three buildings in a satellite, rural village, near a city. All seven buildings had a heterogeneous mixture of students based on socio-economic criteria. All buildings had some racial and ethnic heterogeneity with the two city school buildings having about 40% minorities.

More than 20 teachers were observed on at least five different days for several periods of instruction. Most teachers were observed much more extensively. In addition, project staff talked with the teachers informally to gain insights about the values and beliefs which underlie observed activities. Administrators and students were interviewed, school policy documents reviewed and local newspapers studied to acquire an understanding of the organization and social milieu in which teachers and students work. Moreover, project staff spent several hours per week in the schools and communities to enhance their understanding of the social and organizational context of each school.

FINDINGS

The data that follow are only a part of those acquired in these studies which are still in progress. The observations have been selected and cited because of their importance to science teacher education:

1. In the schools studied, the secondary science teachers ranged in age from mid-thirties to mid-fifties and most (75%) were male. Most had excellent credentials -- at least one Master's degree and an average of nearly 20 years of teaching experience. In two of the districts, the rapport between most teachers and many students appeared to be friendly and supportive. Observations of interactions in these two districts between and after classes suggests very wholesome adult-youth relationships. In the third district, there was little evidence of friendly, supportive relationships between teachers and students. The social ambiance of this district was marked by an absence of interaction between students and teachers, both within and outside of classes; teachers and students seemed aloof from one another in both instructional and social contexts.

   Similarly, the interactions between the research team and teachers in the three districts paralleled the interactions between students and teachers. In two districts, research team members generally were accepted cordially and there were open interactions between teachers and researchers. In the suburban district, three of nine teachers were open and receptive to observation and dialog, but others were more guarded.

2. Interactions between administrators and teachers in each of the three districts were very different. In the village districts, administrators demonstrated enthusiasm about teachers' work and appeared to spend a sizable portion of time interacting with teachers and students about matters relating to instruction and discipline. These administrators observed classes, were visible in the corridors, and met with teachers more frequently than did administrators in the other two districts.

   In the suburban district, interactions between administrators appeared to be cordial although superficial. Even in cases where teachers were severely in need of help with instructional improvement, dialog with administrators was nearly non-existent and apparently undesired by either teachers or administrators. Instead, each went about their own work with little regard for the other.

In the urban schools, the relationship between teachers and administrators appeared almost stereotypic of traditional labor-management interactions. These schools experienced a flood of memoranda from both district and building offices, which were often received by grumbling teachers.

3. Even with this range of administrator-teacher interaction, teachers in all three districts had a very high degree of autonomy in determining instructional content and academic standards. "Boundaries" regarding acceptable content and standards were ill defined. In the three districts, each teacher appeared to have considerable latitude in determining what should be taught as part of any course.

   In some cases, notably in the village district, science teachers in grade nine, for example, developed their tests collectively, thus providing some coordination at that level. Science teachers in grades seven and eight also collaborated on test development in this district.

   Most other teachers worked quite independently both in selecting content and setting standards. There was little coordination among teachers of the same courses and almost no articulation from grade to grade. Three factors appear to have contributed to this situation: (1) There is relatively little advocacy for careful coordination, articulation, content selection, and the collective establishment of standards in science. Curriculum directors and principals appear to be "spread too thin," and department heads typically lack time, authority, and training needed to provide leadership in this area; (2) many teachers and administrators appeared to lack time, interest, and skills needed for collective deliberation and decision making regarding content selection and determination of standards; and (3) energies of many science teachers were directed into activities that were unrelated to science teaching. Science teachers' outside activities were diverse; many coached sports, some had outside businesses, others had demanding hobbies and/or family responsibilities. Nearly all filled their out-of-school time "to the brim." As a result, they tend to be interesting, enthusiastic people who bring a collective richness to the school, which reflects their own personal development in a variety of areas. However, some approached teaching rather "worn out" from their demanding extramural activities.

   On the other hand, relatively few science teachers engaged in continuing improvement of their understanding of science, its societal applications, and science teaching as a serious part of their activities. Few science teachers read professional journals in science or science teaching. Few read even those journals designed to convey information about new developments in science to lay persons such as Discover, Science '84, or Scientific American. Public television programs, such as NOVA, provided an important source of information about developments in science and technology for teachers, but there were no equivalent data sources regarding new concepts and developments in science teaching.

Given this situation, in which there was a lack of leadership, an absence of essential skills and interests, and a diffusion of energies in other directions, collective discussion and decision making regarding content and standards for science did not occur. Instead, individual teachers made these decisions often with a minimum of reflection, frequently under the pressure to teach one lesson after another, interspersing tests as needed.

4. The initiative for decisions on content and standards, therefore, extended to individual teachers who relied on immediately available tools for help. And what was most readily available? Textbooks! In many ways, textbooks provided teachers with a way to escape a difficult situation. Texts provided a body of content, organized in what authors and publishers perceived as a coherent manner, complete with activities and assessment items. Complex and difficult decisions about content and standards were reduced to the simple selection of chapters and questions from the text.

Observations in these classrooms, however, suggest that relatively few teachers used textbooks effectively. Some try to "cover" every page and nearly all of the activities. This resulted in an encyclopedic approach to science with complex concepts being addressed at a rate as high as ten per class period. Some others made selections which tended to diminish the logical order and interconnectedness of the content. Many did not help students learn how to read the densely written material. Direct instructions on how to use data tables, charts, graphs, and illustrations to enhance understanding of the subject matter content was rare.

The most common failing was the reduction of cognitive demand of the subject to a recall of factual information. Comprehension of relationships, applications of scientific principles in the real world, interpretation of data, and creative synthesis of ideas received minimal attention as the perceived need to "cover the text" seduced teachers into accepting knowledge of the vocabulary as satisfactory evidence of students' learning.

Further, because texts often provided limited examples regarding application of scientific principles, and because teachers themselves have limited knowledge about applications, students rarely had opportunities to learn how to utilize scientific knowledge in practical ways. Thus, young people were asked to memorize definitions from the text and solve abstract problems at the end of each chapter, while the connections between textual content and events outside of school were rarely made explicit. Is it any wonder that students kept asking teachers the crucial question, "Why are we learning this?"

Finally, texts typically emphasized "what is known" (concepts and principles) to a far greater extent than "how we know" (processes of science). Therefore, text-based instruction tended to provide students with minimal experience with scientific processes.

5. About 15 percent of instructional time in many science classes in the three districts studied was given over to audio-visual aids, predominantly films. Tapes of TV programs, typically copied on the school's video recorder, and filmstrips were used frequently. During four months of observation, by five observers, the following were noted:

    a. Films and videotapes were usually shown when they became available. Frequently, the subject matter of the film or videotape had little correspondence with the subject matter of prior or subsequent lessons. Usually, films had been ordered at least six months in advance and alternative dates provided to the supplier. Thus, teachers did not know when a specific film was scheduled until its arrival and it had to be returned within a few days. Videotapes of network programs were not retained, largely due to the need to recycle the tape for subsequent use. Thus, they were played for classes usually within a few days of taping, even though they did not relate to the ongoing topic of instruction. As a consequence, about 15 percent of institutional time was given over to a pleasant diversion, rather than being an integral component of an instructional plan.

    b. Films and videotapes were usually shown without discussion. Teachers typically said, "We have a film today. It is about ____________ which we will be studying in a few weeks (or which we studied a few weeks ago)." Then, students were directed to take notes or to watch without writing. The film was run, students usually watched quietly with little talking or horseplay. When the film ended, the teacher rewound it while students talked with one another. The teacher asked, "Are there any questions about the film?" There usually were none. The teacher then showed another film or students were directed to do a homework assignment from their text. Serious or protracted discussion of a film occurred following fewer than 10 percent of the films shown over the four-month period.

    c. The cognitive content of many films was very dense. During a 15-minute film, students were flooded with over 50 terms each representing a complex concept or principle. The observer, familiar with the content, tried on occasion to write down the terms as they were given. Frequently, he could not keep pace. Is it any wonder that students responded with a blank stare to their teacher's query, "Are there any questions?

6. Computers were notably absent in science instruction in the three secondary schools. Computer programming classes were taught, usually by mathematics teachers, and computers were utilized in business classes, especially by more advanced students in word processing. But in science classes, students had direct experience in less than 1 percent of the classes observed. When asked for reasons underlying this situation, teachers cited lack of: (a) access to hardware, (b) availability of appropriate software, (c) essential knowledge and skills, (d) time in the curriculum for additional activities utilizing computers, and (e) time to plan, prepare for, integrate, and manage computer-based science activities for students.

IMPLICATIONS FOR TEACHER EDUCATORS

The findings described above point to many problems which science teachers in secondary schools and science educators in universities cannot solve independently. Collective action is needed to alter the conditions of schooling and the character of interactions among teachers, administrators, students, university personnel, and others who influence educational policies, practices, and budgets. However, these data do have important implications for university science educators which fall into three categories denoted by the following questions:

1. How can teachers and administrators be more adequately prepared to engage in collective decision making regarding choices of content and standards -- decisions which cannot be made appropriately by individuals, acting in isolation due to the need for articulation from grade to grade?

2. How can teachers be more adequately prepared to teach about technology, applications of science, and their societal consequences?

3. How can teachers' instructional skills be enriched, especially regarding use of textbooks, audiovisual aids, laboratory activities, demonstrations, field trips, and discussion?

Collective Decision Making

Description and analysis of skills for collective deliberation and decision making are an important part of the literature of the field of general curriculum (Schwab, 1971; Valence, 1983). Professionals in that field have emphasized the importance of these skills for decades. Because of the "grass roots" nature of curriculum planning in U.S. schools, part of the professional education of all teachers and administrators should include development of skills for collective deliberation and decision making about the content and standards in the curriculum. Specific foci of skill development should be on definition of goals and objectives of instruction, selection of content to be included within (and excluded from) the curriculum, and specification of criteria by which student learning will be assessed.

Technology, Applications, and Societal Consequences

Most university science instruction is deficient regarding technology, applications of science, and their societal consequences. The programs required for teacher certification tend to emphasize basic knowledge in science. In most cases, graduate study of science adds further basic knowledge and tends to be even less related than undergraduate work to technology, applications, and societal issues. Thus, as secondary teachers have long recognized, the study of science beyond a certain level will not add appreciably to their ability to teach secondary school students. Consequently, many teachers stop enlarging their understanding of basic scientific knowledge.

Teachers whose background includes technology, applications, and their societal consequences may have an advantage in that further study in these areas can affect their ability to teach more effectively. Teachers with broader and more current knowledge of applications, technology, and societal issues can make science instruction more pertinent to their students and provide them with knowledge and skills that will be useful in their daily lives as citizens, workers, and consumers. But if this is to occur, new courses and programs must be developed by universities and new certification standards must be employed.

Enriching Teachers' Instructional Skills

It was apparent from many of the observations in schools that instructional skills needed improvement. Often, more appropriate strategies for instruction could have been selected such as discussion following films and laboratory activities, use of demonstrations to clarify conceptions and principles, and helping students learn how to interpret information in texts or other written materials. At other times it was apparent that teaching skills simply were poorly applied. In both selection of strategies and their application, many practicing teachers needed help. Part of this help can be incorporated in preservice instruction, but much of it needs to be available to practicing teachers in the form of graduate courses in methods of teaching and non-credit workshops.

Specific workshops on how to use textbooks or films effectively in teaching secondary school science would fill an important need. Workshops and courses that include a "coaching" component would be useful as well, since experienced teachers could benefit from constructive feedback in the same way that experienced golfers profit from coaching about their swing.

It was surprising to note the absence of computers in science classes at a time when computers have received so much attention from media, in the educational literature, and from educational leaders. The reasons for the discrepancy between observations of practice and the general perceptions of potential applications of computers in science instruction must become an item for deliberation, research, and development among science educators.

An Additional Idea

Perhaps a fresh concept is needed, as well. In this spirit, the author suggests that science teachers could be encouraged to view their career not only as their occupation, but also as one of their hobbies. Teaching secondary school science requires more than can be accomplished in an ordinary work week. Planning, organizing, teaching, correcting papers, maintaining the laboratory, helping students, preparing demonstrations, and interacting with students socially and intellectually will more than fill every working day. So what about keeping abreast of new developments in science and pedagogy? What about expanding understanding of science-based societal issues, new technology, and recent applications of science? A few teachers combine their careers into both occupation and hobby. They read widely about technology, applications of science, and about their societal consequences. They also read about science teaching and are active in professional organizations. These individuals have other hobbies and interests, as well. They are not narrow and uninteresting. They are excited about their work and remain vibrant and intellectually alive throughout their career. The author and the reader can name examples of people who combined their careers into both occupation and hobby and who have had a strong influence on us.

The concept of career as occupation and hobby is one that teacher educators should nurture. It will involve development of specific skills and attitudes which are, as yet, unidentified. However, it will include skills relating to information acquisition, interpretation, and use, and attitudes regarding the importance of continuous professional development in a complex, but exciting field about which professionals can never know enough!

SUMMARY AND RECOMMENDATIONS

Teacher educators have many new challenges as the educational establishment in the U.S. strives to help youth attain a broader spectrum of instructional objectives in science. This author intends to contribute a richer and deeper understanding of classroom practice and the forces which shape it and in turn, to influence teacher educators to consider matters of classroom practice in planning programs for teachers both before and during service. It is in this spirit that the following recommendations are offered:

1. New courses and programs are needed which provide teachers not only with a comprehension of important scientific principles, but which also help teachers understand technology and applications of science, and their societal consequences. These should be part of the preparation of all science teachers. Special opportunities need to be provided so that practicing teachers can acquire knowledge in these areas since few possess knowledge in these domains. Certification requirements will need to be altered in most states so that courses of this type can become a standard part of a teacher's background.

2. More attention needs to be given to providing both prospective and practicing teachers with instruction in methods of teaching science

including strategies for effective use of textbooks, films, discussions, laboratories, demonstrations, and field trips. It may be desirable to introduce a "coaching" model to aid teachers in improving instructional strategies.

3. Courses and workshops are needed for teachers and administrators which nurture skills and attitudes required for collective deliberation and decision making regarding choice of content and standards of instruction. Here also, certification standards need to be altered to include a requirement in this skill area, at least for all administrators.

4. Science educators need to examine ways in which computers may enrich science instruction and the factors which impede their utilization as part of the instructional program of secondary schools. The different uses of computers as tools for managing and aiding instruction, for simulation, and for laboratory data collection and analysis need to be clarified.

5. Teacher educators should strive to help prospective practicing science teachers acquire the attitudes and skills needed to enable a view of science teaching as both occupation and hobby. This concept may be important in helping teachers be more effective, prevent "burnout," and enjoy continuous professional growth. The concept appears to work well for some teachers. Making it a reality for more than just a few science teachers will require further development and action.

The ideas contained in this paper may be perceived as somewhat unorthodox. Perhaps they are; and that may be the result of many months of observation in secondary schools. However, given the current state-of-the-art, some unorthodox ideas may be needed!

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PART II

MODELS FOR PREPARING SCIENCE TEACHERS FOR S/T/S

CHAPTER 4

RATIONALE FOR REVISION OF SCIENCE TEACHER EDUCATION

Paul J. Kuerbis

INTRODUCTION

In April 1983, the National Commission on Excellence released its report, A Nation At Risk: The Imperative for Educational Reform. In its report, the Commission concluded that, "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people" (National Commission on Excellence, 1983, p. 5). This is just one of many reports released by various study groups, commissions, or experts during the past two years. While there has been much debate over the accuracy and the educational perspective taken in the reports, one is forced to agree that the reports have brought education to the forefront of political debate and focus.

To date, the reports have focused largely on perceived flaws in our kindergarten through high school educational system and, consequently, steps which must be taken to strengthen K-12 education and return it to its former condition of excellence. For the most part, the various reports have called for a solution based on the axiom that more is better and, therefore, with a little more effort we can overcome any weakness. Thus, we have been told that we need more hours in a school day, more days in a school year, more English, mathemathics, science, and computer science in the curriculum, more discipline and homework for students, and more pay, respect, and more demanding standards for teachers. Even the current national administration seems content to focus on two simplistic "more" efforts: returning prayer to the classrooms of America (i.e., more prayer) and tax credits for parents to send their children to private schools (i.e., more money for those who already have it). And, of course, our scientists and science educators aren't entirely opposed to this approach. We have recently argued successfully for more money in the Science Education Directorate of the National Science Foundation. While some of these "mores" can no doubt lead to more effective ducation, as a recent Kappan editorial stated, "All the reforms that you . . . can dream up won't amount to diddly unless they affect what goes on between teacher and students behind classroom doors" (Phi Delta Kappan, 1984, p. 514). The focus has been on the educational system and schools, while we should be examining one of the most, if not the most, significant variables in the educational process: teaching.

For the most part, the reports have said little about teacher education. Some suggestions have been made for current teachers (i.e., inservice education), but even fewer suggestions have been made for preservice training of teachers. The report of the National Science Board Commission on Precollege Education, Educating Americans for the 21st Century, only mentions that prospective teachers should have a limited number of effective education courses which should incorporate current findings in the behavioral and social sciences and practice teaching under a qualified teacher (1983, p. 31). Yet, the report claims to be a plan of action which will result in student achievement that will be the best in the world by 1995. Fortunately, it does urge liberal arts colleges and academic departments to assume a much greater role in teacher training, a point to be considered later.

PATHWAYS TOWARD IMPROVEMENT

More recently, the Exxon Education Foundation hosted a meeting of educational leaders for the purpose of exploring essential steps for achieving fundamental improvement of science education. Among the many recommendations were several directed at preservice teacher education. In the group's view, a model K-12 curriculum should take a science, technology, and society (S/T/S) orientation which would require some significant redirection of both preservice and inservice teacher education. Although the group did not recommend specific changes, they did urge that, "early attention needs to be given to the development of models for preservice teacher preparation which are based on the new science and technological literacy perspective." (Exxon, 1984, p. 13). Perhaps teacher educators should be thankful that a national agenda for teacher education has not been spelled out. Clearly there is a need to assume a proactive position on science teacher education soon, before we are forced to react to a specific set of recommendations. The author's intent, therefore, is to outline some ideas for a model for the improvement of science teacher education. Such a model may, indeed, be a misnomer, for the author is not certain that there has ever been a model or plan for science teacher education. Rather, it has simply been a part of whatever happened "over there" across campus, in the School, College, or Department of Education (SCDE's). In formulating this model, it is assumed that "science education" is redefined to include the new S/T/S perspective and, therefore, that "science teacher education" also includes this new orientation. It is this author's thesis that now is the time to risk: to take a chance and to venture in creating a pattern of science teacher education which responds to the new science and technology outlook and which also includes a new vision of the structure or form of teacher education. Although the model would be generalized to other sciences, perhaps to other subject areas or grade levels, it is intended here to serve as framework for the initial preparation of secondary level science teachers.

A MODEL FOR THE IMPROVEMENT OF SCIENCE TEACHER EDUCATION

How does one risk, venture forth, take a reasonable chance for the improvement of science teacher education? How does one prepare prospective teachers to cope with a society which is undergoing continual change? Indeed, how does one hit the proverbial moving target? That is, how can teachers be prepared for a society which will be markedly different in 10, 20, or 30 years? How can teacher educators and scientists alike be involved in this process? What is our responsibility and role in the education of science teachers? Is it simply a matter of increasing entrance standards, encouraging the best students to enter the teaching field, or insisting that a major in a science field will be completed by all candidates? The author questions this currently accepted position. It seems likely that this acceptance may lead us to neglect a necessary restructuring of the teacher preparation process.

Does it mean dismantling SCDE's and incorporating the teacher preparation into the science departments? Probably not, although it is tempting to respond "yes," if for no other reason than to cause our science colleagues to examine more carefully the science and art of teaching.

What is needed is to revolutionize the teacher training process. There is a need to go well beyond a plan that simply incorporates a series of isolated ideas, such as those just enumerated, or one that is based on a single paradigm (e.g., behavioristic) that may be popular at a certain time. Rather, a model should incorporate the best of theory and research concerning teaching. In the end, one should be able to examine the model and answer in the affirmative that adherence to it will lead to excellence in teaching and in student learning.

RETHINKING TEACHER PREPARATION

It is beyond the scope of this paper to detail the philosophy, theory, and research on teaching and teacher education. However, D. H. Kerr (1983) has provided a good review of competencies we should expect of teachers. Ernest Schuttenberg (1984) has provided a review of some of the criticisms of teacher education and a review of recommendations made over the years regarding components necessary in teacher preparation programs. Drawing on these ideas, Schuttenberg has posited a three-dimensional model of teacher education, somewhat like Mortimer Adler's three-column model for general education which Adler outlined in The Paideia Proposal (1982). Shuttenberg's work is incorporated into the following model for science teacher preparation. This new model has two major components, which the author identified as content and form.

CONTENT

The author believes that there are three parts to the content component in a science teacher preparation program.

Academic Competence

Academic competence consists of knowledge, skills, and understanding. "Knowledge" means the acquisition of organized knowledge. But what knowledge is of most worth for a prospective teacher of science? It seems self-evident that the basic requirements for a major in a science field would be the minimum. But a science major structured for the undergraduate is one largely designed for a prospective scientist, not an interpreter (teacher) of science. Moreover, what coursework in S/T/S context is available and which is adapted to the needs of the prospective precollege teacher? Futhermore, the suggestions of the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology (1983), as well as those of experts like Paul DeHart Hurd, point out the need for a change in the K-12 curriculum. Specifically, the Commission urges that:

> The curriculum in grades K-6 should emphasize a study of nature and biological phenomenon. In the life sciences of grades 7-9, the emphasis should be upon understanding oneself as a human being. General biology in the high school (grade 10) should emphasize biology in a social/ecological context (p. 98).

Does the existing standard undergraduate major in a science area prepare a young teacher to teach this new curriculum? Probably not. Either changes must occur in the science major, or certain courses or concepts must be added to the major so that the knowledge background of a prospective science teacher matches the coming changes in the K-12 curriculum. Clearly, scientists in higher education need to examine this issue.

The prospective science teacher must also acquire the intellectual skills of learning. Mortimer Adler, in The Paideia Proposal (1982), refers to these as reading, writing, speaking, listening, calculating, problem-solving, observing, measuring, estimating, and critical judgment. Clearly, these are not the sole domain of the sciences and so it is essential that the prospective science teachers include in their preparation courses and experiences from a variety of the liberal arts.

One should also expect the prospective science teachers to gain an understanding of basic ideas and values, especially in the sciences, but in all areas of academic study, as well. Science cannot exist in a vacuum. The application of science-based technologies must be understood and discussed openly, inside and outside of science courses.

In addition to the categories and fields of study just mentioned, the candidate must also acquire a knowledge of social psychology, group dynamics, and human learning and development through coursework in areas such as anthropology, psychology, sociology, and philosophy. Knowledge in these disciplines creates the basis for the second part of the content category of this model.

Instructional Understanding

Instructional understanding means the knowledge, skill, and understanding which pertain directly to the act of teaching or interpreting science. The following four points should be considered.

1. The candidates need to see instructional strategies modeled throughout their undergraduate years. The models the candidates see during these years are very powerful, for the chances are great that they will teach as they have been taught. It isn't enough for teacher educators to lecture on the techniques of small group instruction, or provide their students with written summaries of instructional strategies. It is not even enough for teacher educators to model various instructional approaches which, fortunately, many of us do. Prospective science teachers will still wonder if these strategies are appropriate outside of teacher

education and will ask why they didn't see these strategies in the context of science if they are, indeed, effective and legitimate strategies. In short, the candidates need to experience a variety of strategies throughout their collegiate years, but most importantly in the area in which they are going to teach science. The dilemma is perhaps best summed up by an old saying: "What you do speaks so loudly that I cannot hear what you say."

2. Teacher educators must find ways to incorporate the growing body of research in teaching/learning into their courses in ways which impact positively on the teacher candidates. The growing gap between what research says and what is practiced in schools must be narrowed, and can be if one starts by effectively acquainting prospective teachers with the research. The thought here concerns two significant bodies of scholarship: the effective schools/effective teaching body of research and the research on teaching and learning styles. While it is necessary to interpret with caution the effective schools research, it nonetheless deserves our full and careful consideration. For those of you unfamiliar with this research, it suggests, among other things, the conditions when certain strategies, for example small group and large group instruction, may be used most effectively. The research on teaching and learning styles, for example, provides teachers with a framework in which to individualize. For years many have envisioned individualized instruction to mean teaching the same material to all students, while merely adjusting the pace for each student. However, recent learning styles research, much of it carried out in classrooms, has given considerable insight into the varying approaches by which humans process information and the varied environmental, sociological, and psychological factors which influence the effectivness of learning (and teaching!). Together, both areas of research can give important clues to the teacher on how to select an appropriate strategy in a given context for a particular student. Both also demonstrate that teaching is a complex act, an intellectual activity when it is practiced in light of available theory and practical research. It points out that teacher education programs must be preparation programs rather than training programs, for we are dealing with preparing the candidates to deal effectively with new situations, not just training them to respond in fixed ways to recurring situations. Such preparation must occupy a large part of any program, while the traditional socialization aspects of teacher education programs should decrease in emphasis. Currently, quality education courses occupy too little time in a candidate's preparation program (perhaps only 25 semester hours out of a total of about 120).

3. It is important that the candidates are familiar with educational technologies such as computers and that they are familiar with ways in which new technologies can be utilized to enhance instruction. How computers can be used as an effective teaching tool is still a new frontier. However, this growing body of knowledge must be shared with prospective teachers to encourage them to investigate ways in which the computer and other technologies can be used effectively for

instructional purposes. In the 1984 NSTA Yearbook, Ellis and Kuerbis presented the rationale for inclusion of this area in teacher preparation programs.

4. How can field experiences (e.g., student teaching) best be utilized in acquainting the candidates with instructional understanding? Teacher educators and their programs have often been maligned for not providing courses with a sufficient connection to the real world of classroom teaching. Historically this may have been true, but the institutions with which this author is familiar have made a concerted effort to improve the quantity and quality of field experiences. For most institutions in this country, this is not just a recent effort. For example, at Colorado College, early field experience in a public school setting has been required since 1974 (and actually began informally several years earlier). All "methods" courses include a daily field experience teaching or tutoring in a classroom, and student teaching is a carefully supervised, full-time experience which lasts a minimum of 12 weeks. Are more and earlier field experiences better? One recent study, involving the comparison of candidates in a 12-week student teaching program with those in a year-long internship program, could detect no clear-cut differences in the students after the field work. Perhaps of more concern was the finding that students in both groups increased their concern over pupil control (Silvernail, 1984). Still other studies have determined that by the end of student teaching, prospective teachers became more authoritarian, rigid, impersonal, arbitrary, bureaucratic, and custodial. Are these the qualities we wish to instill in beginning science teachers? The author hopes not! Thus, while firmly believing in field experiences, there is need to discover how to work best with prospective teachers in classroom settings. When and under what conditions should field experience begin? What role can scientists and science departments play in this process?

Developmental Understanding

If academic competence results in knowing that or what and instructional understanding results in knowing how to teach well, then this third category, developmental understanding, consists in knowing the why and wherefore questions of human learning, development, and interaction.

First, the program for the prospective teacher must include a thorough grounding in the psychology of human learning and development, social psychology, and group dynamics. This should include not simply basic tenets, as might be included in certain psychology courses, but must also include examples of these tenets in educational settings and the applications that teachers can make of these tenets. Prospective teachers need to know that principles of human learning and interaction can be used, indeed, must be used to make decisions regarding curriculum and instruction.

Second, the program must include strategies and procedures that encourage or permit the development of the candidates themselves. Prospective teachers need to develop healthy self-concepts. They need to understand their strengths and weaknesses, perhaps by conducting personal, reflective inventories. In turn, they need practice in setting realistic professional development goals. Throughout the program, candidates need to be encouraged to take another's perspective and eventually multiple perspectives or points of view. One of the challenges faced by teacher educators, and alluded to earlier, is acquainting beginning teachers with the research on teaching. The teachers bring to our classes certain views, perhaps even misconceptions, of what strategies, materials, approaches will be effective with K-12 students. How do we assist the candidates in overcoming the narrow, erroneous points of view? The situation is not unlike that which faces science teachers at all levels who would do well to recognize the misconceptions that students have regarding a particular concept _before_ they attempt to teach the concept. Recently, Lillian McDermott (1982) and James Minstrell (1982) summarized their experiences in dealing with science students' misconceptions. Scientists and science teacher educators face a parallel challenge. We need to uncover how best to teach so that our candidates for teaching can learn effective instructional approaches and incorporate them into their teaching repertoires.

There is also a second parallel that should be drawn. If indeed the college science curriculum changes to focus on important societal issues and technology related global problems, then the task of getting college students, including prospective science teachers, to take alternative points of view increases for the scientists. In turn, this should ease the task for the teacher educators or at least set the stage so that science teacher educators can more easily deal with candidates who may have difficulty taking multiple perspectives.

FORM

While the first category of the model addressed the issue of content, the second attempts to provide an answer to the important question: How can the elements of program structure be linked in an effective program? The author has, therefore, labeled this part of the model, form. What form might science teacher education take?

The writings of futurists such as John Naisbitt, author of _Megatrends_, and Linda Tafel, an educational futurist at the National College of Education, suggest that what is needed is to move from a hierarchial model of teacher education to one of networking and cooperation. In teacher education, the hierarchial, sequential, industrial era model has been employed for decades, certainly since the inception of the Normal School in this country. Even today, we continue to have the prospective candidates complete their liberal arts/academic work during the first few years of college, followed by a year or so of professional training in teaching which is topped off by student teaching. We need to break out of this sequential mode and adopt an alternative, collaborative/networking mode. Although "collaboration" is a much overworked word in today's vocabulary, it nonetheless embodies an important principle which should characterize the form of a science teacher education program. The recently released Carnegie Foundation for the Advancement of Teaching report, School and College: Partnerships in Education concludes that:

> If the quality of teaching in America's public schools is going to rise, then the nation's institutions of higher education can no longer afford to sit back as indifferent spectators while the schools struggle with problems they cannot solve alone. New school-college partnerships are required (Maeroff, 1983, p. 42).

The author has already mentioned that the National Science Board has urged liberal arts institutions and academic departments to assume a greater role in teacher preparation. But how do we collaborate? Who should collaborate? Can we ever give up the protection of our individual territories?

There are at least three areas or levels of collaboration which must occur and which will enable us to weave together the content components of the model. First, colleges (in this case science departments) need to collaborate with high schools. Specifically, plans need to be explored that would enable high school teachers to visit with and collaborate with college science professors. There exists a unique opportunity for scientists to share the excitement of research and new technology with high school teachers. Science professors can assist high school teachers in developing curricula, especially in new areas with which current teachers may be unfamiliar. And science professors can gain a greater understanding of the problems and possibilities of teaching students who may someday be in their own classes. Both parties need to share their developing knowledge of and expertise in teaching. In the short term, this kind of collaboration speaks to the inservice training of teachers, but over the long haul, the effects will be felt in preservice education. Collaboration at the student level is also possible and needed. Not only should high school students be freer to move onto and off of college campuses, but perhaps the college science majors can assist their professors in establishing shared realtionships, partnerships, and in the process learn something about teaching as a career option. Collaboration between colleges and high schools is not only possible, but necessary. Either party can initiate such efforts, but let me encourage you at the higher education level to be leaders in this effort.

Secondly, Schools, Colleges and Departments of Education need to collaborate with school districts and high school science departments. Many (by far most) teacher educators have not actively taught in a high school classroom for many years. Many of us are able to visit classrooms with some regularity, perhaps as supervisors of student teachers, but it is clearly another thing to function as the classroom teacher for a substantial period of time. Such a check with reality can be refreshing. Conversely, classroom teachers need to escape on occasion and become renewed through acquaintance with the educational research findings which were referred to earlier. Furthermore, there is a need to explore ways in which field experience, student teaching for example, can be strengthened and used to support the prospective teacher's growing knowledge of effective instructional practices. We must bridge the gap between what SCDE's are teaching the prospective teachers and what the candidates see taking place in K-12 classrooms.

In Colorado, another collaborative effort between teacher educators and public school personnel is already underway. For the past three years, the Colorado Association of Teacher Educators and school district staff development coordinators have joined together annually for a series of meetings designed to explore ways in which the two groups, one largely concerned with preservice education and the other with inservice education, can work together rather than separately and often at odds. It is only a beginning, but the potential good for inservice and preservice teacher education that may come from this effort is very promising. Collaborative efforts such as this need to be greatly expanded. Inservice and preservice educators need to recognize that they function at opposite ends of a continuum, and work to remove barriers.

Thirdly, there needs to be more collaboration between Schools, Colleges and Departments of Education and the various science departments and it must be more than the superficial collaboration of joint appointments. We can no longer expect teacher educators to accomplish in one year the task of preparing teachers. As mentioned earlier, prospective teachers need to see, and be taught through, a variety of strategies long before they reach the SCDE's. Scientists need to model more than just didactic teaching. Is it possible that science teacher educators can team with scientists to explore more effective models of teaching? Hopefully. Is the effective schools research transferable to the college level? We need to find out. What aspects of science can best be taught didactically? Under what conditions and with which students is it more appropriate to use coaching, case studies, or Socratic dialogues? What approaches/materials can help students achieve a better perspective on science and technology related global problems? It appears to this author that there is much to be gained through collaboration and much to be lost without it. It is time to explore ways to cooperate. In our colleges and universities, teaching must become a priority along with research. If students see that college science professors value teaching, if they see teaching as the intellectual challenge that it truly is, perhaps more of them will consider teaching as a career.

But, how do we begin to change? The Carnegie Foundation report, School and College (Maeroff, 1983), suggested that the Master of Arts in Teaching degree, popular in this country in the 1960s be dusted off and infused with renewed vigor. A number of institutions have done so. The University of North Carolina MAT in Science program is in its third year. The program reduces the number of education courses, while recruiting undergraduate majors in the sciences who have outstanding academic records.

The Colorado College, which has had an elementary level MAT program in place since 1969, has initiated a somewhat parallel program which leads to an MAT in Science or in Mathematics. Only highly qualified subject matter specialists who have also demonstrated success with children/students can enter one of the programs. These programs represent a collaborative effort between the College's Department of Education and the College's mathematics and science departments. In the initial stages of program development, informal and formal discussions ensued between the Education Department and the mathematics and science departments. The programs' governance structure was purposely designed to encourage on-going collaborative efforts. An advisory board composed primarily of the chairs of the math and science departments assists the programs' director, who is a member of the Education Department. Furthermore, a mentor team guides each student. The team consists of the director and one member of the candidate's academic major department, thereby providing further chance for collaboration.

The MAT approach is but one option. Other variations, which begin to implement aspects of the model, are possible. For example, the University of Massachusetts (Amherst) has a Masters in Education program entering its second year. This program places emphasis upon the subject matter competence of the candidates, has an extended student teaching period, and includes a semester internship for each student in a major high technology firm, demonstrating that collaboration with the business community may be an important aspect of science teacher preparation for the 21st century.

CONCLUSION

The MAT Programs and their variations represent a start at an implementation of the model which has been presented. None of the programs, including the author's at Colorado College, addresses all parts of the model. Nevertheless, they are important first steps toward implementation, discussion, testing, and revision of the model.

Whether or not one agrees with the model, it is hoped that it can be agreed that there is a need for a model or plan to approach science teacher education. Without some model, which incorporates the growing knowledge base of teaching, we will continue to swing on a pendulum, from paradigm to paradigm depending on the one most popular at the moment. With a viable model we stand a good chance of hitting the moving target mentioned earlier.

The model presented herein needs to be discussed widely, perhaps revised extensively. However, it is of interest to note that the model matches with many of the qualities that experienced teachers have indicated are desirable in their jobs: collegiality, collaborative planning, continuous learning on the job, variety, and school wide participation in curriculum development. So, perhaps the model is not so farfetched afterall. Such a model should be adaptable across the country because it is based on fundamental principles of teaching and learning. The model is intended to establish a broad structural pattern within which there can be variation, depending upon local circumstances.

Whatever one's impressions of the proposal, now is the time to risk, to venture forth, and to create a plan for the improvement of science teacher education within the context of an S/T/S orientation.

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CHAPTER 5

RESTRUCTURING SCIENCE TEACHER EDUCATION PROGRAMS AS THEY MOVE TOWARD AN S/T/S FOCUS

Robert E. Yager

INTRODUCTION

Manuel Justiz, Director of the National Institute of Education (NIE), has proclaimed that "we are facing a crisis of confidence in teacher education" (Justiz, 1984). Such a crisis in exists apart from the major moves in science education to a new content focus and new organizers for school programs. Such change in the structure of science to be included and its accompanying rationale make the crisis in science education deeper and of more concern than is the situation for teacher education generally. Teacher educators not only must face and proceed with changes in traditional matters of teacher education; they must over-haul the whole science teaching major and look anew at what science is (and what it is not); such perspectives must be central in a science teacher education program.

Many have proclaimed the present time to be one of great promise in science education because of the large data base which includes both breadth and depth of information that can be used to plan and execute new programs--both in terms of content and process. Joseph Vaughan, Senior Research Associate of NIE, has outlined those new bodies of knowledge which must be considered by persons interested in improving the quality of the content included in teacher education programs (Vaughan, 1984). Of great importance is the wealth of information dealing with teacher effectiveness. This information suggests specific instructional strategies that are appropriate in a variety of situations. Another kind of knowledge now available to affect the content of teacher education programs is that dealing with the teaching context. Such information provides a means for improving teaching beyond the teaching act, and focuses on district and building management and organization, roles of parents and communities at large, and schools as work places and social environments. A third kind of knowledge now available is that dealing with changes and improvements in school programs. Such knowledge arises from studying a variety of attempts to stimulate change as well as knowledge about the way adults learn and the successes of non-school programs.

Medley (1979) has written extensively and convincingly about fifteen years of research activity concerning effective teaching. Teaching behaviors and classroom conditions which appear to be important are known. Such behaviors and conditions, when studied and understood, may provide research-verified information that can become a new technical core for standard teacher education programs. Certainly science educators and persons interested in considering model S/T/S programs must review this knowledge and such new general programs that may ease the crises that are percieved in all areas of teacher education. These advances are extremely important if science teacher education is to move toward S/T/S focus.

THE TRADITIONAL UNDERGRADUATE PROGRAM: COMPONENTS AND PROBLEMS

Science teacher education has consisted of an undergraduate degree with three basic ingredients, namely a major in science (or, at some institutions, one of the sciences), the general education requirements of the college, and a professional education component. The science major is usually set by faculty in the various areas of science and usually has not differed significantly from the various programs leading to graduate work in one of the sciences and/or preparation for medicine or other related health fields. Often this major (with supporting courses in mathematics and other related science fields) consists of work approaching 60 semester hours, i.e., two full years of preparation. The general education requirement (communication skills, physical education, social studies, literature, foreign language, historical/cultural/humanities) often includes 30 to 45 semester hours of additional credit. Professional education courses often involve 18 to 30 semester hours of credit. When a student completes the general educational and professional sequence in education, there is usually little or no opportunity for electives. In fact, this situation has led many to opt for masters of teaching degrees to permit preservice teachers to complete a few graduate courses in science, to spread out the professional courses over more semesters, and to complete some electives and/or special support areas.

One of the major problems associated with such a standard program has been the relative independence of these separate facets of the program and the relatively small portion that the science educator has controlled (or has been responsible for). For many the science major is an extremely important component and quite naturally it is controlled by persons in the science areas; it often represents over half the entire undergraduate program for the would-be science teacher. Such science majors tend to be very traditional, requiring content-mastery across the subdisciplines in a given department as well as considerable preparation in mathematics and allied science areas. Such programs tend to be "proving grounds" for future graduate students in pre-dentistry, pre-medicine, and allied health fields. Too often the mediocre students in such majors are the ones "counseled" to consider teaching.

The general education requirements are often controversial--with no one person, department, or general administrator being happy with courses which supposedly assure that every undergraduate who is awarded a Bachelor's Degree will be well-rounded. Regardless of the requirement--nearly always in excess of the equivalent of one full year of study--the persons in teacher education usually have little or no "say" in the matter. After all, such requirements help develop students in ways that make them deserving of a college degree--something possed by only 16 percent of the American public.

The sequence required for teaching certification usually must meet certain conditions specified by the state. In recent years these have included special work in computers, human relations, mainstreaming, and similar considerations which reflect current issues and concerns in education. Most programs include an introduction/history/philosophy of education course, some study of educational psychology, seminars/courses dealing with the special issues mentioned previously as well as such skills as preparation of graphics and skill with use of audiovisual devices, exploratory school experiences, one or two methods courses, and student teaching (often half of the total program). To make these requirements (usually translated into courses) fit into a meaningful 20-30 semester hour program is difficult at best. In fact, the difficulties usually result in moves to graduate programs for teacher certification--a direction some states have taken for all students. College and school of education faculty often have special reasons for desiring the total program to be broken into courses-specific ones of which are taught by persons with special expertise in the various areas where particular requirements exist. This often leads to teacher education programs with little overall structure, developmental features, and/or sense of interconnections. Instead, the components are each "checked-off" as they are completed. A given student is lucky if the various courses and instructors are not in competition as to time spent, value, use, and basic philosophy. All too often the person teaching a methods course is in conflict with persons teaching other courses as well as in conflict with the philosophy possessed and the methods employed by the cooperating teacher who heads the student teaching experience for a given preservice student.

The problems of this kind of teacher education program have been known, studied, and debated for over 25 years. Tamir et al. (1978) analyzed the changes in focus which have occurred during this time frame. These workers also proposed a check list to use in assessing one's own program. The basic features of a model program were reported to include:

1. Experiences in teacher education are planned for a span of several years and are integrated with the total academic program.

2. The program consists of a broad curriculum that goes beyond the separate science disciplines.

3. The nature of science in a historical, philosophical, and social perspective is a central component.

4. The program is based upon stated objectives, generally expressed in performance terms that delineate a variety of instructional skills and competencies.

5. Experiences for improving communication and interpersonal relationships are included.

6. Preservice teachers are actively involved in a variety of teaching experiences; a significant number of these occur with students in the public schools.

7. Experiences are provided in evaluation and in the application of research to learning and teaching.

8. The preservice program is but a first step in a continuous cycle of professional growth and inservice education.

9. The program is based upon a continuing evaluation of needs and program effectiveness; it includes the continuous assessment of the skills of the individual preservice teachers (pp. 85-86).

THE S/T/S FOCUS

These problems are serious enough for the traditional teacher prepared to teach standard science courses. They demand attention and solution. However, as schools and teachers move to an S/T/S focus, these problems become even more difficult. Unless programs change significantly, every new science teacher will be wholly unqualified for S/T/S efforts before he/she ever begins teaching. Effective S/T/S teachers deserve (must have) some experience with S/T/S themselves.

Norris Harms provided the framework for the problem in the Project Synthesis report. He said:

> One overarching responsibility faces every person associated with science education, from the local to the national level. The responsibility is to rethink the goals of science education in light of basic educational philosophy and the unique role science plays in all of our lives, and to redirect the science education system toward those redefined goals. We are confident that other persons who make an in-depth study of the status of science education will find pre-college science education almost completely dedicated to the academic preparation goal, and that they will agree that major changes are critically needed. We are also convinced that other thoughtful persons will come to conclusions similar to ours; that the goals of preparing the majority of students to use science in their everyday lives, to participate intelligently in group decisions regarding critical science-related societal issues and to make informed decisions about potential careers in science and technology are equally as important as the goal of preparing a minority of students for more advanced coursework in science. Thus, a new challenge for science education emerges. The question is this: 'Can we shift our goals, programs and practices from the current overwhelming emphasis on academic preparation for science careers for a few students to an emphasis on preparing all students to grapple successfully with science and technology in their own, everyday lives, as well as to participate knowledgeably in the important science-related decisions our country will have to make in the future?' (Harms and Yager, 1981, p. 119).

To meet this challenge will require a new kind of teacher education program. Persons who have won at the game required of K-12 students (who are instructed that one "first-needs-to-know" what teachers know and what content is in the book in order to earn the right of doing it again at the next grade level) are the ones who go to college to complete more science--usually with the same promise (i.e., if you succeed, you will be selected for more study in a given discipline at the graduate level). The best S/T/S teachers will not be those who have succeeded with traditional K-12 science courses and undergraduate college majors. In a very real sense their science preparation will "get-in-the-way" of using science in an S/T/S sense.

Miller and his colleagues at the University of Northern Illinois studied science attentives and the function of the school and science programs in producing them (Miller, Suchner, and Voelker, 1980; Voelker, 1982). This work suggests that existing science programs and teachers fail with 90 percent of all students enrolled in the schools. Such research is a powerful voice for moving toward S/T/S programs and the production of teachers interested in and able to develop and to teach such programs. Voelker calls for such teachers as he closes his summary of the attentiveness studies:

> If we want a science program that is truly responsive and responsible to the citizen in a scientifically and technologically oriented society, we must elevate current and future citizen concerns. We cannot assume that curricula which emphasize traditional cognitive knowledge and an understanding of the scientific process will lead to an understanding of the science-related issues confronting society. Neither can we assume that such traditional curricula will assist our student-citizens in applying their scientific knowledge and processes to these issues. Some sacred cows of the science curriculum must be eliminated. But the short-term trauma this sacrifice may elicit will be replaced by a long-term gain for all citizens (Voelker, 1982, p. 79).

Still another line of research that provides further argument for the validity of an S/T/S approach while also arguing for a new kind of science and science education preparation for the preservice teacher is in the area of cognitive science. Recently Klopfer (1984) offered a comprehensive review of this whole area. Central to this research is the fact that large numbers of students "learn" school science--at least they perform as teachers expect on tests--but without real understanding--or "belief" in what they purport to know. There are major breaks between school science and the real world. Most students resort to the real world (that is, their own experiences that provide meaning for the world) for their understanding as opposed to the text-teacher-school explanation of the world. Many college students, including science majors, have been shown to have naive theories of the world. It is probably fair to conclude that some of the worst in this regard are the persons advised into science teaching. Completing more complex/abstract science courses does not help students--even college students--to develop real understanding of the world.

Rustum Roy, one of the leading proponents of the S/T/S movement has termed S/T/S as the glue of science for most people (Roy, 1983); on another occasion he has called S/T/S the soil for science. Roy heads a large S/T/S project for NSF. In the brochure for the project he says that:

> STS is a strategy for teaching the 'sciences' through Science, Technology and Society subjects and concepts. It holds that building and maintaining interest in, motivation for, and retention

> of technical concepts and information is best accomplished by grounding such teaching in societally relevant issues--where science and technology impact students' lives and their day-to-day world. The STS subject matter itself is, moreover, invaluable as a badly needed integrative theme in education and preparation for twenty-first century citizenship (Roy, 1983, p. 23).

If this is the situation for school science, experiencing S/T/S as a critical and significant part of the preservice program of every science teacher is an imperative.

AN S/T/S FOCUSED PROGRAM

What would such a program be like if the preparation of S/T/S teachers were to become the major effort in science education? Although there may be a variety of ideas and programs that should be tried during the years ahead, it is apparent that all should of necessity have some common elements. It is also apparent that all such programs will be very different from the traditional programs described previously, especially with respect to the typical science major. In fact, it is probably true that the completion of a science major leading to a graduate program or to medical school may be a detriment to preparing a person to help students with issues related to S/T/S.

Thinking in terms of "courses" may not be the best approach; however, it is "where-we-are" at most institutions. Haberman (1984) has recently provided an interesting history for the course concept in higher education. It could be in the best interests of science education--and the S/T/S focus--if experimental colleges developed teacher education free of courses per se. For most it may be appropriate to think of facets of a complete program in terms of individual or a series of courses. These courses would, of necessity, be quite different from standard science courses found in most departments and from the teacher education sequence described earlier. More of the program could resemble general education experiences--at least those in the most innovative institutions--those evaluated by such measures as the new ACT-COMP test (1981).

Obviously some work in basic science is important--but maybe not so important as it is (was) in preparing to teach science as it has been. More important than a teacher "knowing" science is a teacher knowing how to inquire, how to find answers, how to use material and human resources. This is quite a departure from tradition; the NAEP reports (Hueftle, et al., 1983; Yager and Yager, 1984; Yager and Bonnstetter, 1984) all indicate that science teachers are seen primarily as information sources. High school science teachers rarely, if ever, admit to not knowing science information. Effective S/T/S teachers cannot be known as primary sources of information. Perhaps 30 semester hours of science (only half of the credit for most science majors today) would be adequate for an S/T/S teacher. This does not mean that such a teacher would not find more science desirable or that such a teacher would not desire to complete more during his/her professional life. However, 30 semester hours of work that includes preparation in each of the major areas of science (i.e., biology, chemistry, physics, earth science) should be an adequate beginning for the preservice program.

An S/T/S teacher needs direct experiences with applications of science--the world of technology. Courses in engineering, nutrition, health, agriculture, forestry, conservation, industrial arts, home economics, and other applied fields could be important. Perhaps faculty in these applied areas could organize special survey courses for would-be science teachers. Or, perhaps some of their introductory courses would be appropriate. It is believed that every S/T/S teacher should have about 10 semester hours of credit in such applied science fields. An S/T/S teacher needs preparation in special fields of the social studies. Courses in sociology, geography, economics, and world history could be important. At times some special interdisciplinary/interdepartmental courses developed for general education purposes can be excellent additions to the preparatory program for the S/T/S teacher. It is recommended that every S/T/S teacher complete at least 10 semester hours of work in these areas.

An S/T/S teacher needs background in the philosophy, history, and sociology of science. At many institutions such courses are being developed and are proving attractive to general education students. Background in all three areas is critical for persons preparing to teach science, especially those preparing for S/T/S. It is desirable for the preservice student to complete a minimum of 10 semester hours of work in these areas.

Lastly, it is recommended that every preservice science teacher have direct collegiate experience with an S/T/S course. Such courses should focus on societal issues, require extensive reading and analysis, include individual and group projects, provide experience with collecting information and direct evidence to use in resolving some local/community issues related to science and technology. Students should deal with real people, community leaders, citizens, the press, advocacy groups, industrial workers, and others. Every student should experience at least three such courses--perhaps one during student teaching so that his/her students could be a part of the S/T/S experience. It is recommended that such S/T/S courses comprise a minimum of at least 10 semester hours in the total program.

If the five components just elaborated are viewed as the content major, it would include 70 semester hours. The subtotals would be:

Basic Science, including some work in all basic disciplines	30 s.h.
Applied Science, including engineering and other vocationally oriented fields	10 s.h.
Social Studies, including sociology, geography and economics	10 s.h.
History, Philosophy, and Sociology of Science	10 s.h.
Science-Techology-Society "Courses"	10 s.h.
Total	70 s.h.

It is apparent that such a "major" surpasses the total hours required for the typical discipline-based science major which most preservice science teachers commonly complete at the current time. However, it is believed that some of the courses in the recommended 70 s.h. major would also fulfill many of the usual courses in general education. Only the skill areas and perhaps literature/humanities/art would be additional requirements if they were not already satisfied as part of a typical high school program.

The teacher education sequence remains as an important part of a total program for preparing S/T/S teachers. Certainly some of the recommendations and positions mentioned initially should be included--and in a science education context whenever possible. It is surely known that, when a proper and meaningful context is not provided, many ideas and concepts remain abstract and unused. The research affecting teacher education in general could fall in that realm if the persons involved with special programs (such as preparing S/T/S teachers) do not help with the context and build upon it throughout the entire program.

The best S/T/S teacher can be prepared when appropriate (science education) staff are involved throughout a four- or five-year program. Certainly it is rare to find a student who can select a variety of courses to meet requirements and who sees or senses their relationships or value. An informal and sensitive faculty member can help with the synthesis, the growth, and the insights.

Early and frequent experiences in schools with pupils is a vital part of any meaningful and successful preservice teacher education program. Such work in schools as a part of the real society--as a means of dealing with youth--as an opportunity to motivate students to take action, to use knowledge, to debate, to make informed decisions--is an essential ingredient for a preservice teacher education program aiming toward science teachers who are able in and comfortable with an S/T/S approach.

Science educators should be an integral part of the total program at each level--each year. Proper preparation of science teachers requires more than occasional advice concerning choice of typical science courses, instruction in one (or even two) science methods courses, and supervision of student teaching (with occasional school visits, conferences, and weekly seminars). Frequent association with prospective students in one methods course is woefully inadequate as a means of preparing an S/T/S teacher.

Science educators are needed to help select the basic science experiences, to structure the technology/applications of science courses, to identify appropriate experiences (courses) in the social sciences, to develop (perhaps teach) the philosophy, history, and sociology of science courses that will be useful to the preservice student, and to create (perhaps teach one or more) of the S/T/S courses. This means that more science educators are needed with a more direct role in the preparatory programs.

ESSENTIAL CHANGE - AN AWESOME TASK

No one would expect other professionals to be prepared with the involvement of many faculty from various other departments, with heavy use of practitioners in the field who were largely prepared in another age to do a different job, with a general faculty in charge of graduation requirements set by another college (arts and sciences), with the "central" instruction provided by one professional in a single course (science methods).

Perhaps it is time for science educators to close ranks--perhaps we need to set standards in such a way that programs built around a single professional in charge of but one course (science methods) would not be approved. Perhaps we have too many programs with too few professionals to handle the job at hand.

The S/T/S movement seems to be upon us--albeit somewhat belatedly in the U.S. As we all strive to prepare more and better teachers to face tasks only dreamed about but five years ago, it is apparent that science teacher education must be improved and strengthened as soon as possible. Surely traditional programs headed by generalists and persons unaware of the S/T/S focus have no chance to resolve these problems. Unfortunately, such programs may be the cause of the failure of science education. As more and more teachers are needed--often to fill positions defined in a most traditional way, the situation will get worse. If new teachers cannot bring new ideas, we all lose. If new teachers are more equipped for schools, students, and programs of the 1960s, we seem hopelessly lost. The task is awesome; the changes are essential. Educating a better citizenry--a total citizenry--for the 21st century may be our only hope for survival of the human race. Can we do less than try with all our might and intellect?

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CHAPTER 6

PREPARING UNDERGRADUATE SCIENCE TEACHERS IN S/T/S: A COURSE IN THE EPISTEMOLOGY AND SOCIOLOGY OF SCIENCE

Glen S. Aikenhead

INTRODUCTION

The education literature indicates five basic implications for the training of teachers. This literature and its implications are succinctly reviewed here as a context for describing a senior education course offered at the University of Saskatchewan. The course, "Perspectives from the History of Science: The Epistemology and Sociology of Science," addresses four of the five basic implications. The purpose of the course is to provide science majors with S/T/S content and to prepare them for introducing such content into conventional science curricula.

RATIONALE

In his book Teaching and Learning About Science and Society, John Ziman (1980) developed a useful rationale for S/T/S education. Whereas conventional science education "conveys to the student images of science, images of the scientist, and images of the role of science in society, which are damaging to science, to scientists, and to society itself" (Ziman, 1980, p. 30), the fundamental goal for S/T/S education is "not to replace conventional science education nor to modify it out of all recognition, but to correct its unconscious bias with complementary themes" (Ziman, 1980, p. 30). This rationale suggest three implications.

> Implication 1. The training of teachers for S/T/S education requires a correction of unconscious, misconstrued biases of teachers about science and technology.
>
> Implication 2. The training of teachers for S/T/S education requires an opportunity to develop a knowledge base with respect to themes complementary to the corrected content (the epistemology and sociology of science).
>
> Implication 3. The training of teachers for S/T/S education requires.an acquaintance with curriculum materials appropriate to these themes.

Ziman's concern with the cognitive content of teachers' views about science is enriched by Holford's (1980) suggestion that teacher education needs to focus on four major competencies:

1. Teach about the technological implementation of science in such a way that students can provide defensible opinions on science-related social issues;

2. Foster students' growth in decision-making capacities;

3. Seek connections between science and technology in lessons; and

4. Become more knowledgeable about the commercial world and to be aware of career opportunities that science and technology in school facilitate.

Holford describes a number of teaching skills that support these competencies; skills such as handling class discussions, moderating debates, and composing questions to be used in analyzing newspaper articles. Holford's view offers another implication.

> Implication 4. That training teachers for S/T/S education requires the experience of teaching science lessons with a S/T/S emphasis in order to develop appropriate teaching skills.

It is encouraging that the British view of S/T/S education expressed by Zinman and Holford corresponds to the North American definition of S/T/S education. Both Piel (1981) and Roberts (1982) view S/T/S education as teaching scientific subject matter with a different emphasis; that is, teaching from the social and technological context of science (what Roberts, 1982, calls the "science, technology and decisions" emphasis) rather than from the conventional perspective of the specific scientific discipline (what Roberts labels the "structure of science" and the "correct explanations" emphasis). Let us take the specific example of teaching chemical equilibrium. On the one hand, the concept can be taught in the context of making sense out of arguments by government agencies over acid rain and soil conditions. This is an S/T/S emphasis. On the other hand, chemical equilibrium can be taught as a logical extension of reaction kinetics to show how the discipline of chemistry is an organized body of knowledge with interrelated concepts. This is a structure-of-science emphasis.

Defining S/T/S education in terms of emphasis provides us with a general strategy for preparing teachers to teach S/T/S content. Methods courses should deal with a shift in emphasis rather than with a revolutionary overthrow of conventional science instruction. This shift is primarily accomplished by changing the context in which the subject matter is taught. However, this shift harbors pervasive and far-reaching consequences for the teacher (Aikenhead, 1980):

1. from viewing students as receptacles for scientific truths, to recognizing students as consumers of science education constructing their own meaning;

2. from identifying learning with the short-term objective of memorizing and doing types of quantitative problem solving, to identifying learning with the long-term objective of interpreting one's personal world according to one's interests and social responsibilities;

3. from viewing the primary goal of science education as preprofessional training for post-secondary science and technology programs, to

accepting the primary goal as helping students (including future scientists and engineers) develop into informed, responsible citizens; and

4. from evaluating students on their ability to master isolated bits of subject matter, to evaluating their ability to make meaning out of everyday occurrences such as newspaper articles or television messages. (From a student's point of view, an S/T/S emphasis would be as rigorous as conventional courses but would be significantly more relevant.)

Such pervasive shifts in a teacher's perspective on teaching yield a further implication.

> Implication 5. That training teachers for S/T/S education requires an opportunity to rethink one's goals for teaching science and to reformulate what one values as legitimate science instruction.

These values guide a teacher's decisions on what to present in class, how to present it, and how to evaluate student learning (Aikenhead, 1984). These values are usually learned during a teacher's university science training. For most teachers with at least a few years of experience, these values are very resistant to change (Olson, 1982). Thus, it seems important for prospective teachers to clarify and, if necessary, to reformulate their values by studying an authentic view of the scientific enterprise. From the author's perspective it seemed best to provide an option to integrate these ideas into the university science teacher education program.

PERSPECTIVES FROM THE HISTORY OF SCIENCE COURSE

The B.Ed. program for science majors at the University of Saskatchewan requires a student to complete a "half course" (13 weeks, 3 hours per week) dealing with the epistemology of science. Students may choose "Perspectives from the History of Science," an introduction to the epistemology and sociology of science, or they may choose among several Arts and Science half courses in the philosophy or history of science. For example, a major in chemistry education would take, among other courses, four and a half courses in chemistry, a half course dealing with the epistemology of science, a chemistry methods half course in curriculum and instruction, plus a generic teaching skills half course.

Overview of the Course

In "Perspectives from the History of Science," students investigate: how scientists know what they know, what kind of knowledge this is, and how the social milieu interacts with scientists and their knowledge. A historical perspective affords insights into these issues by shedding light on the intellectual and social development of the scientific enterprise, including problems and controversies of the 1980s. Emphasis is placed on analyzing scientific events from a number of different perspectives. In addition, attention is constantly paid to the implications for teaching high school. Specifically, the course addresses implications 1,2,3, and 5 stated above.

Required Reading for the Course

The readings either supplement lectures or serve as preparation for class discussions and debates. There is a fair amount of reading. This quantity of reading is necessary for students to investigate a new area of study in a comprehensive way. The course could easily serve as an individual reading course. Required reading includes:

1. Aikenhead, G. "Teaching Science Today, Relevant to 2001 A.D." Teacher Education, 23:58-76, October 1983.
2. Cohen, I. B. The Birth of a New Physics. Garden City, NY: Anchor Books, 1960.
3. Goldstein, M., and I. Goldstein. How We Know. New York: Plenum Press, 1978.
4. Holton, G. The Scientific Imagination: Case Studies. New York: Cambridge University Press, 1978.
5. Kuhn, T. The Structure of Scientific Revolutions (2nd ed.) Chicago: University of Chicago Press, 1970.
6. Mendelsohn, E. Values and Science: A Critical Assessment. A three-lecture series given at the 23rd national convention of the National Science Teachers Association, Los Angeles, March 1975.
7. Roller, D. (Ed.) Perspective in the History of Science and Technology. Norman, OK: University of Oklahoma Press, 1971.
8. Skipp, J. "Regina v. Herbert, Coombs and Sparks." Canadian Criminal Case, 28:423-439, 1975.

Principal References for the Course

A number of references have proven useful for additional exploration of topics discussed in class:

Anderson, T. and B. Kilbourn "Creation, Evolution, and Curriculum." Science Education, 67 (1):45-55, 1983.

Barman, C. et al. Science and Societal Issues: A Guide for Science Teachers. Ames, IA: Iowa State University Press, 1981.

Barnes, B. and D. Edge, (Eds.) Science in Context: Readings in the Sociology of Science. Cambridge, MA: MIT Press, 1982.

Butterfield, H. The Origins of Modern Science. New York: The Free Press, 1957.

Contant, J. B. (Ed.) Harvard Case Histories in Experimental Science (2 Vols.). Cambridge, MA: Harvard University Press, 1957.

Dampier, W. C. A History of Science. New York: Cambridge University Press, 1978.

Factor, L. and R. Kooser. Value Presuppositions in Science Textbooks. Washington, DC: National Science Foundation, 1981.

Gauld, D. "The Scientific Attitude and Science Education." Science Education, 66 (1):109-122, 1982.

Holton, G. and R. Morison (Eds.) Limits of Scientific Inquiry. New York: W. W. Norton, 1979.

Judson, H. F. The Eighth Day of Creation: Makers of the Revolution in Biology. New York: Simon and Schuster, 1979.

Knowledge and Power course team. Waurn Ponds, Victoria, Australia: Deakin University, 1979.

Latour, B. and S. Woolgar. Laboratory Life: The Social Construction of Scientific Facts. Beverly Hills: Sage, 1979.

Mahoney, M. Scientist as Subject. Cambridge, MA: Ballinger, 1976.

Newton, D. Science and Society. Boston: Holbrook, 1974.

Open University course team. "Science and Society." Units 33 and 34 of Science Foundations Course. Bletchley, Buckinghamshire, U.K.: Open University, 1971.

Ravetz, J. Scientific Knowledge and its Social Problems. New York: Oxford University Press, 1971.

Samuel, E. Order: In Life. Englewood Cliffs, NJ: Prentice Hall, 1972.

Schroeer, D. Physics and its Fifth Dimension: Society. Reading, MA: Addison-Wesley, 1972.

Science in a Social Context course. Boston: Butterworths, 1977.

Shamos, M. Great Experiments in Physics. New York: Holt, Rinehart, Winston, 1959.

Toulmin, S. Human Understanding. Princeton, NJ: Princeton University Press, 1972.

Wessel, M. Science and Conscience. New York: Columbia University Press, 1980.

Ziman, J. M. Teaching and Learning About Science and Society. Cambridge, MA: Cambridge University Press, 1980.

Course Outline

The specific reading associated with a particular class is indicated by a number in brackets. The numbers refer to the "required reading" listed previously.

Class

1 Introduction. Nature of scientific facts. (3)

2 Cholera case study: the work of John Snow. The subjectivity of scientific facts and their social relevance. (3)

3 Marijuana court case. The subjectivity of classification schemes and their social relevance. (8)

4 Case study on heat: the work of Joseph Black and Count Rumford. The development of scientific knowledge, its intellectual and human dimensions. The theory-laden nature of facts. (3)

5 & 6 Characteristics and limitations of science. (3)

7 The concept of thema--one of eight different perspectives for analyzing scientific events. (4)

8 The Millkan-Ehrenhaft controversy case study. Different world views defined by different themata and different social backgrounds. (4)

9 Different views toward science: the super-rational Apollonians versus the mellow-loving Dionysians. (4)

10 Greek science. Origins of modern metaphors and background to the Renaissance. (2)

11 Middle Ages/Renaissance science. The social context which shaped the institution of science and its values. (6)

12 Kepler and Galileo. Instigators of scientific values. (2)

13, 14, 15 The overthrow of the Aristotelian paradigm, culminating in the work of Newton. (2), (4), (6)

16 Midterm exam.

17 & 18 Science in a social context. Science as a cultural phenomena. Science interacts with the politics of a society. The anachronism of scientific values in the 20th century. (3), (4), (6)

19 & 20 Decision making on socioscientific issues. (References)

21 Evolution-creationism controversy, an application of the epistemology of science and the politics of curriculum.

22, 23, 24 Kuhnian paradigms. Arguments supporting and negating Kuhn's view on the development of scientific knowledge. (5), (7)

25 & 26 Teaching high school science. Curriculum materials available. A repertoire of methods. (1)

Course Assignments

In addition to a midterm and final examination, students are graded on their ability to analyze scientific events in terms of specific perspectives that are developed in their reading and in class. Students debate the Ptolemaic versus Copernican systems during a mock Sorbonne meeting of 1601. Their preparation of this debate is assessed. By writing a term paper, students explore a special area of personal interest and are evaluated on their ability to analyze scientific events.

CONCLUSION

During the 13-week course, students study the characteristics and limitations of science and the social context of science (both the social system internal to science and the society external to science). Thus students continually correct their misconceptions about science and technology. At the same time, they develop a knowledge base from which they can plan science lessons and evaluate student learning. These education students are also more conscious of classroom instruction in S/T/S because the course makes constant reference to high school teaching, and because the course ends with an explicit study of available curriculum materials. Skills such as using a newspaper article to probe socioscientific issues are also practiced.

By studying "Perspectives from the History of Science" before finishing their science courses at the university, students are able to rethink their goals for teaching science and are able to re-evaluate their values concerning what counts as legitimate, authentic science. This would seem to be a potent method for training teachers for S/T/S education.

Unfortunately, at our university we do not have control over the placement of our students for their internship experience (15 weeks). Some students will work with teachers sympathetic to S/T/S education, while others will not. We do not have sufficient resources to guarantee our students effective experience in teaching S/T/S lessons for the purpose of developing appropriate instruction skills. However, our course does provide them with the necessary background to move in that direction.

REFERENCES

Aikenhead, G. S. Science in Social Issues: Implications for Teaching. Ottawa: Science Council of Canada, 1980.

Aikenhead, G. S. "Teacher Decision Making: The Case of Prairie High." Journal of Research in Science Teaching, 21 (2): 167-186, 1984.

Holford, D. G. "Training Science Teachers for 'Science-Technology-Society' Roles." A paper presented to the 2nd International Symposium on World Trends in Science Education, Trent Polytechnic, Nottingham, U.K., July 1982.

Olson, J. "Classroom Knowledge and Curriculum Change: An Introduction." In J. Olson (Ed.), Innovation in the Science Curriculum. New York: Nichols Publishing, 1982.

Piel, J. "Interaction of Science, Technology, and Society in Secondary Schools." In N. Harms and R. Yager (Eds.), What Research Says to the Science Teacher, 3, Washington, DC: National Science Teachers Association, 1981.

Roberts, D. "Developing the Concept of 'Curriculum Emphases' in Science Education." Science Education, 66 (2): 243-260, 1982.

Ziman, J. Teaching and Learning about Science and Society. Cambridge, MA: Cambridge University Press, 1980.

CHAPTER 7

INSERVICE SCIENCE TEACHER PREPARATION IN S/T/S: PERSPECTIVE AND PROGRAM

Barbara S. Spector

INTRODUCTION

Making the interaction of science, technology, and society (S/T/S) an integral part of students' formal schooling in science K-12 requires that teachers change what they presently do in science classes. If factors that influence teachers to change their behaviors are considered in the design of teacher education programs in S/T/S, the likelihood of S/T/S becoming part of every youngsters' school science experience can be increased.

It is believed that the dominant factor influencing teachers to change their behavior is the degree to which they perceive the potential for deriving personal satisfaction from a change. The degree of congruence existing between teachers' definitions of the role of a science teacher and the role required by an innovation influences whether new behaviors will be tested and to what degree (Spector, 1984).

LEGITIMATIZING S/T/S IN SCIENCE CURRICULA

The first step in a teacher training program is to create an acceptance of the legitimacy of S/T/S as an appropriate part of precollege science. A study of teacher training needs (Spector, 1984) revealed that teachers generally perceived that teaching about the interaction of S/T/S was not congruent with the role of a science teacher. They perceived that only the structure of the science discipline, the accrued body of knowledge which includes the concepts, facts, theories, and laws which have been generated by scientists should be labeled science K-12. In limited instances, teachers raised the point that science process skills were legitimate content, but training for those skills was not conspicuous in the instructional design of many science courses.

What was perceived as legitimate subject matter to be included under the label science K-12 appeared to be derived from three sources:

1. The textbook. Teachers rely on textbooks to determine classroom curricula and frequently local school districts' curriculum guides. There is little or nothing about S/T/S in most textbooks.

2. Teachers' perceptions of college admission requirements. In many schools, parents and administrators put pressure on teachers to insure that students study that which will facilitate the students' admission to college. Colleges do not as a rule show any interest in S/T/S being in science courses.

3. College science courses which teachers complete. It is traditional for potential science teachers to be required to take the same science courses in undergraduate school, and frequently in graduate school, as those students who plan to be specialists in science. The study of applied science and technology is deliberately excluded from those courses.

Thus, the message from those segments of the educational enterprise which teachers encounter most consistently discourages the inclusion of S/T/S in precollege science. Consequently, teachers project little potential for personal satisfaction if they change their teaching behaviors to include S/T/S. It is understandable that (1) the suggestion to include S/T/S in science courses frequently meets with teacher resistance (Spector, 1984), and (2) there were few precollege courses in the U.S. which included teaching about S/T/S (Piel, 1980).

There are several ways to legitimatize the study of S/T/S in school science, thereby enabling teachers to view it as congruent with their roles and having potential to bring satisfaction.

1. The most direct route is state mandate. For example, the Florida State Department of Education, in response to state legislation enacted in 1983, developed student performance standards in science which will be tested statewide. Four out of the twelve standards require teaching that generally falls under the S/T/S umbrella.

2. The publications, presentations, and advocacy work of national trend setters, individuals, and organizations in science education who are urging that S/T/S become an integral part of the K-12 curricula represent another strategy to help teachers accept the legitimacy of S/T/S.

3. Making teachers aware that the continuation of recent funding for science education is tied to political and business/industry perceptions that there is a need for technologic and scientific literacy to facilitate maintaining our economy and the defense of our nation will help legitimatize S/T/S in school science.

4. An effective strategy, but probably the hardest to achieve, is to have universities make it known that science courses which include a foucs on S/T/S are desirable for admission to college, and to have university science courses used in the education of teachers altered to include S/T/S.

ADVANTAGES OF S/T/S TO TEACHERS

Having created acceptance of S/T/S as legitimate, a second step is to help teachers recognize the benefits they can derive from including S/T/S in science courses. Two potential advantages of S/T/S to teachers are (1) that students become more cooperative, interested learners with greater probability of achievement, and (2) teachers can engage in classroom discussions on topics which excite students without feeling guilty that instructional time is being used for something that is not part of the course of study.

Policymakers in many states are increasing the science requirements for graduation. Therefore, the number of students enrolling in science classes involuntarily is increasing. Teachers are facing more students who profess no interest in studying science and perceive the science classroom as a place for exposure to irrelevant information with a high probability of failure.

Most science courses in secondary schools are based on the higher eduation model of basic science in isolation from real world application and implications and are not appropriate for the 97 percent of the students who will not become specialists in scientific fields.

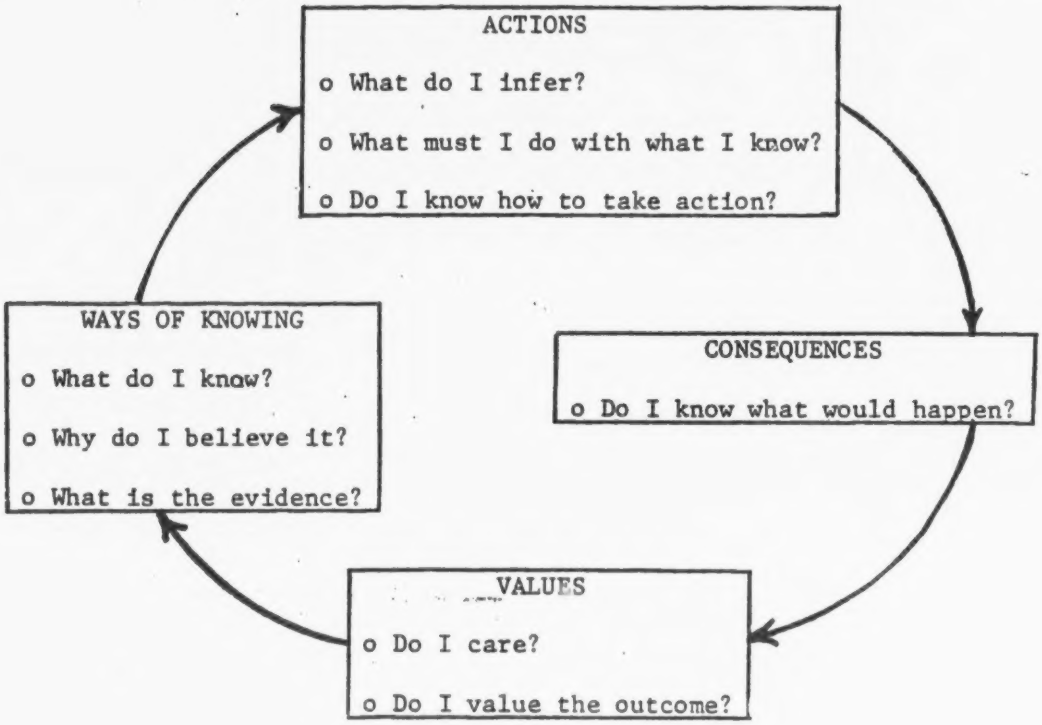
The introduction of applied science and the focus on technology captures the imagination and motivates students. Consequently, those students who are now being required to take science in order to graduate are more likely to be interested in science set in the context of S/T/S. Researchers in cognitive science provide insight to explain why this is a reasonable expectation.

The discussion cycle in Figure 1 (Rowe, 1982) provides insight into the way the inclusion of S/T/S could motivate a learner. People consciously or subconsciously tend to address the questions in Figure 1. People who prefer to work abstractly focus on ways of knowing. Others find that the practical application of new knowledge fascinates them. They focus on actions and consequences. Some people are interested in issues and values. They focus on the interaction between technology and society (Rowe, 1982).

Students who describe school science which focuses on "Ways of Knowing," (particularly, "What do I know?") as irrelevant, boring, and impossible to learn are expressing need to attend to the parts of the cycle commonly omitted in science classes, the "Action," "Consequences," and "Values" parts of the cycle. By making S/T/S a legitmate and significant part of the study of science those parts of the cycle are included and serve as built-in motivators.

Four key points from cognitive science synthesized by researchers at the University of North Florida (Betkouski, 1984) support the concept that S/T/S increases the potential for student interest and learning success.

1. Importance of meaningful learning. Storage in and retrieval from memory are facilitated by the use of meaningful clues, both cognitive and affective. S/T/S issues are emotionally charged to a greater or lesser degree. This emotion provides clues that facilitate storage and retrieval of scientific and technologic information students learn. In the preceeding discussion cycle, the aspect that asks "Do I or does anybody else care?" provides affective clues which serve as strong memory hooks. Successful experiences provide positive affective clues which expedite learning. Many students already know a great deal about technology from boats to rockets. Infusing S/T/S gives them an opportunity for success which they might not otherwise have. In addition, technology and social issues have potential to



ACTIONS
- o What do I infer?
- o What must I do with what I know?
- o Do I know how to take action?

CONSEQUENCES
- o Do I know what would happen?

VALUES
- o Do I care?
- o Do I value the outcome?

WAYS OF KNOWING
- o What do I know?
- o Why do I believe it?
- o What is the evidence?

Figure 1

stimulate student interest in learning the basic science on which they are based. The fact that students are apt to experience more success with S/T/S in a science course contributes to the appropriateness of the expectation that S/T/S will make reluctant learners more successful and therefore more interested in science.

2. Procedural (skill) learning is accomplished only through well-structured practice: A current goal for science education is to educate students to be effective problem solvers who apply science to enhance their well being as individuals and as citizens in their communities. Since there is little known about the transferability of problem solving skills from one type of problem solving skills on S/T/S issues.

3. Confronting naive theories: Naive theories about the way the world works are based on limited experience or study. Students perceive no need to confront their comfortable naive theories if concrete examples of the "real world" are not used in class. Therefore, student behavior does not change to reflect the correct theory and a purpose of studying is defeated.

4. Teachers assume the role learning mediators: A teacher needs to assume the role of learning mediator using techniques such as probing questions, modeling, and simple explanations. This helps students identify where errors in their reasoning have occurred. Real world examples stimulate a "need to know" in students and the desire to change their reasoning, thereby correcting a naive view of the workings of a particular part of the world (learning a correct theory).

S/T/S makes learning basic science relevant to students. Too many students expect school learning to be usable only to permit passage into a higher course in the academic sequence or just to get a grade. Because transfer does not happen automatically, students need a teacher's guidance to make the connection between basic science, its application, technology, and personal and societal decision making. Some teachers already provide that guidance. However, they commonly feel pressed for time and wonder whether they dare to take the time. Herein lies the second advantage to the teacher of infusing S/T/S in the curricula. The teacher is relieved of the guilt and the anxiety of making tradeoffs between using time to "cover" all the basic science that is required in already overloaded science courses and allowing time for that which makes science relevant and meaningful.

Prior to the acceptance of the legitimacy of S/T/S in a science course, teachers often found themselves in enthusiastic discussions with a class stimulated by a question from a student who was exploring applications and the value of applying science to real world situations. At the end of the period the teacher would think "Good grief! I only did ten minutes of the fifty minute lesson I had planned. I 'wasted' the entire period."

With S/T/S as a legitimate part of the curriculum, teachers can capitalize on those things that excite students, thereby making the teacher's life in the classroom easier and more pleasant. This would result in an increase in the teachers' personal satisfaction which can be expected to influence them to increase the S/T/S experiences.

CONCEPTS TEACHERS NEED TO LEARN

What do teachers need to learn if they are to incorporate S/T/S into science K-12? The concept map in Figure 2 suggests components and linkages which teachers need to comprehend if they are to change what they presently teach in science to that which is appropriate for all students who live in our rapidly changing scientifically and technologically based democratic society.

The existing cadre of teachers of science K-12 consists primarily of people trained in higher education programs which did not include the study of technology nor the philosophical, historical, and sociological aspects of science. These studies would enable teachers to comprehend the interrelatedness of basic science knowledge, process skills, problem-solving skills, technology, and society, all of which are essential if one is to make school science relevant and to guide precollege students in the application of science to personal and societal decision making.

Post baccalaureate teacher training programs must provide teachers with opportunities to study and internalize the concepts and processes in Figure 2 and to develop instructional designs and evaluation procedures which are compatible with the structure of this S/T/S content.

The concept map (Figure 2) depicts interrelationships among the ways people acquire and use knowledge, what people value, how people express their values in society and influence the questions and problems which scientists and engineers may investigate, and the subsequent generation of scientific knowledge and development of technologies, all of which influence daily life and the essence of society.

Contemporary society is influenced by knowledge people acquire in a variety of ways. Science is one way people have developed to acquire knowledge about themselves and the world in which they live. Some other "ways of knowing" are religion, aesthetics, philosophy, etc. These "ways of knowing" with or without the influence of science, determine human values. Human values, what society accepts as ethical and moral acitivity, determine society's influence on the scientific enterprise.

The primary influence on the scientific enterprise comes from the control of resources which support research and the use of the products of research. Society's control of resources for basic science research influences what scientific questions will be investigated in order to add to the accrued body of scientific knowledge.

Engineering, the application of science to solving human problems, is also limited or accelerated by society's control of resources and other political mechanisms which determine the human problems that will be addressed, how much of the science knowledge base will be applied to solving a

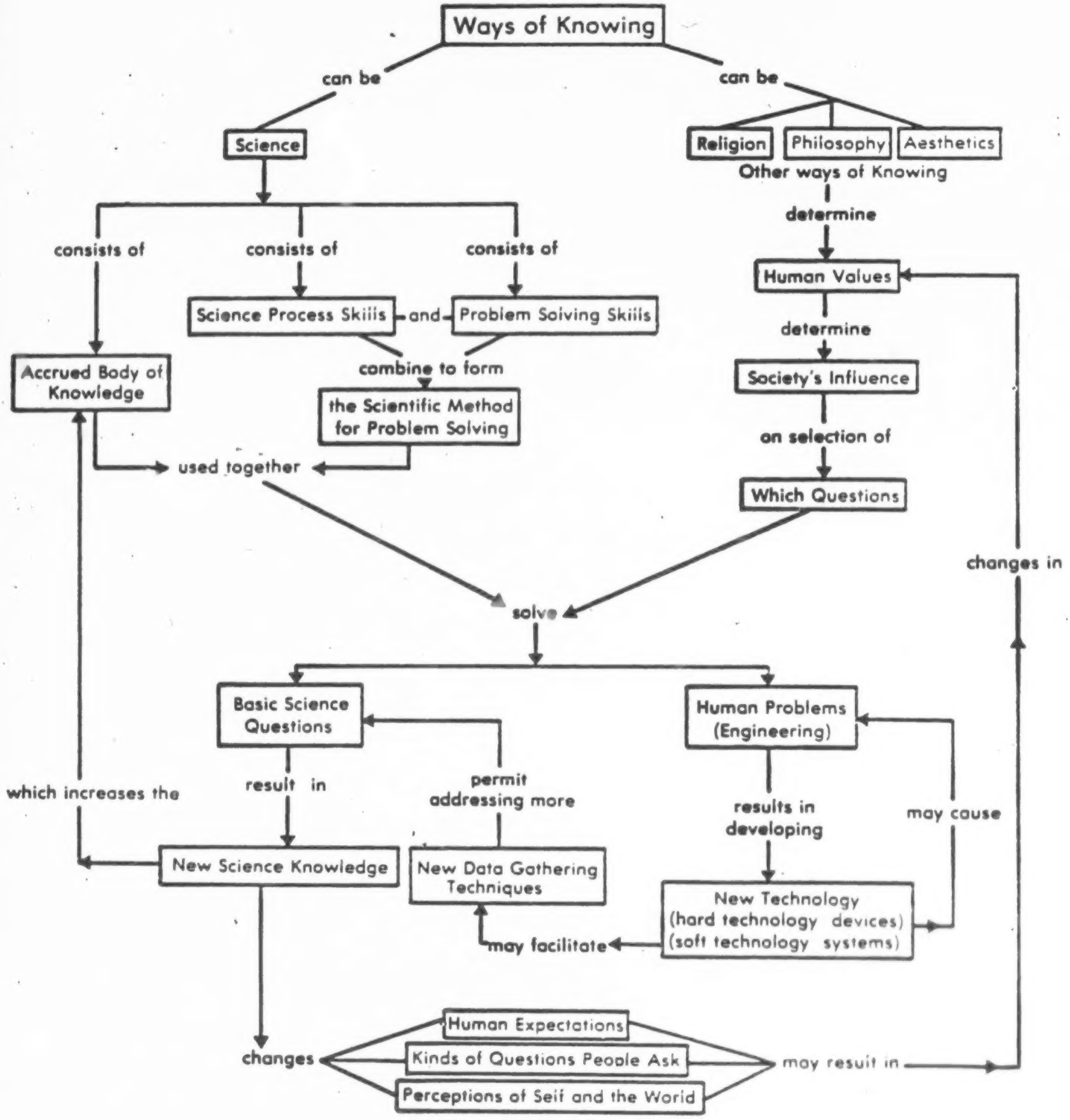

Ways of Knowing
can be
can be
Science
Religion
Philosophy
Aesthetics
Other ways of Knowing
determine
consists of
consists of
consists of
Human Values
Science Process Skills
and
Problem Solving Skills
determine
Accrued Body of Knowledge
combine to form
the Scientific Method for Problem Solving
Society's Influence
on selection of
used together
Which Questions
changes in
solve
Basic Science Questions
Human Problems (Engineering)
which increases the
result in
permit addressing more
results in developing
may cause
New Science Knowledge
New Data Gathering Techniques
New Technology (hard technology devices) (soft technology systems)
may facilitate
Human Expectations
changes
Kinds of Questions People Ask
may result in
Perceptions of Self and the World

FIGURE 2

problem, and how long engineers will be able to apply scientific problem-solving skills to a particular human problem. Solving a human problem results in developing new or modified technologies. These technologies may be devices (hard technology) or systems and procedures (soft technology). The use of the emergent technologies is also influenced by societal values.

One use of new technology is to facilitate further inquiry into a basic science question, the answer to which will ultimately result in more information being added to the accrued body of knowledge called science. The increase in scientific knowledge changes the kinds of questions people ask, their perceptions of themselves and the world, their expectations, and causes them to reevaluate the way they apply their values to influence the scientific enterprise.

When the new technologies are used to mitigate a human problem there are spinoffs and side effects. Sometimes a spinoff or side effect causes a problem which needs to be studied, thereby increasing the list of human problems waiting to be solved. The network of science, technology, and society interactions involves many interactions which are reciprocal.

To fully understand these interrelationships one must explore assumptions about the meaning of science as compared to other ways of knowing and become familiar with the way human values have determined the path of science and development of technology through study of the history of science. In order to prepare students for the world in which they will live as adults, the teacher must not only understand the past but must become fully cognizant of what is going on in contemporary times. "The most reliable way to anticipate the future is by understanding the present" (Naisbitt, 1982, p. 2).

An analysis of contemporary American society by Naisbitt in 1982 reveals that we are undergoing a turbulent restructuring of American life as we pass from one era to the next, from an industrial society to an information society. The rapid growth of science and technology has been providing the impetus for the restructuring of American society. There has been an exponential growth of science knowledge during the twentieth century which facilitated concomitant increases in technologies at a rate faster than any other time in human history. In addition to the technologies we use which shape our lives, the

> sciences have become a critical social force because they fundamentally transform the way we perceive the world, the questions we ask and the expectations we hold. If we are to cope with these changes, as well as with our still emerging abilities to build or destroy, then we need to know more about whence these things come, about science about the general discoveries of our time (Hammond, 1984, p. 9).

There are factors that recur at different times and places and are likely to recur in one's own future. Clues to cause and effect sequences, which may take place again given similar circumstances, can be found in the history of the scientific enterprise. Some of the recurring factors working in the process of change in science, in technology, and their impact on society were identified in Connections by James Burke in 1978. They are:

1. "...an innovation occurs as the result of deliberate attempts to develop it." (p. 289)
2. "...the attempt to find one thing leads to the discovery of another." (p 289)
3. "...unrelated developments have a decisive effect on the main event." (p. 289)
4. Motives such as war and religion can act as major stimuli for the development of innovations. (p. 290)
5. Accident and unforeseen circumstances lead to many innovations. (p. 290)
6. Physical and climatic conditions influence the development of innovations. (p. 290)

DESIGNING S/T/S TEACHER EDUCATION PROGRAMS

A teacher education program aimed at helping teachers incorporate S/T/S in precollege science would require the study of the socio-history of science and technology and engender the concepts delineated in Figure 2. Sample goals which could be used to guide the design of a program leading to the acquisition of those concepts and providing real world examples would include ascertaining the meaning of science; describing the structure of science; presenting a picture of present and past relationships between science and the public; addressing a variety of science and technolgy related ethical considerations; explaining the educational implications for science instruction K-12 which are inherent in the nature of science, its meaning and structure; discussing the historical aspects of science and technology; and contributing to the increased numbers of women and minorities in science and technology.

A full set of goals and specific objectives which could serve as a check list for planning instruction to meet the preceding goals is in Appendix A. The amount of detail included to meet each specific objective would determine the amount of contact time and the credit hours assigned to a study of the socio-history of the scientific enterprise. Traditional university credit units would probably range from three to nine credit hours.

How does one determine which specific science concepts, which technologies, and which societal issues should be included in an education program for teachers? One approach to ascertain which items are most appropriate for teachers is to begin with these questions: (1) Who should make that determination and (2) who should design the learning experiences with which to educate the teachers?

In states or school districts where student outcomes for S/T/S have been defined, it is appropriate to use those outcomes as a base for determining teacher learning experiences (Figure 3).

In states where there are no specifications for S/T/S content in precollege curricula, a desirable approach to determine what will be taught to teachers is for university faculty to assemble several teams, each of which is composed of a scientist, social scientist, engineer or technologist, and a science educator. Each team could follow this procedure: (1) participants would identify the lead issues in their own fields; (2) each individual would identify the five current research topics in his/her own field that he/she perceives to have potential to impact society in the next two decades; (3) all would share the lists of basic science topics, current important technologies, and social issues with the total team; and (4) the group would analyze the lists to identify those items which are related to each other. Those items with the most relationships would be given priority and used as the basis for designing learning experiences for teachers.

The learning experience could begin with the analysis of a social issue, followed by identification of the technology involved in the priority social issue and the science concepts upon which the technologies and social issues are based. This approach reflects a process suggested for teachers to use with precollege classes when they elect to use current societal issues as course organizers.

A second approach parallels what teachers could do with their students in courses that are organized to display the logic and structure of the discipline. For example: (1) the science team member would be asked to list topics which reflect a broad-based survey of the discipline and to identify the three key items in each topic; (2) the technology person would be asked to identify those technologies that have been developed, are developing, or might be developed; and (3) the social scientist would be asked to delineate the personal and societal decisions that individuals may face as a result of the development of the technologies.

A third approach to determine which science concepts, technologies, and social issues should be included for teachers would be to first list key technologies in society. Second explore which prerequisite technologies enabled them to emerge and what basic science concepts preceded the development of particular technologies. Third, indicate social issues related to the technologies.

In addition to providing teachers with an understanding of the components engendered in S/T/S and real world examples for each concept and interaction in S/T/S, teacher education programs need to provide significant instruction and guided practice for teachers in translating S/T/S content to instruction suitable for precollege students at various levels.

Teacher education programs should therefore help teachers:

1. determine optional formats for incorporating S/T/S in a school science program, i.e., add-on courses, units, or infusion;

Intended learning outcomes (goals) for precollege science students
↓
determine
↓
what the precollege science teacher needs to know and do
↓
which determines
↓
the training needed by a precollege science teacher
↓
which determines
↓
the design of university teacher training programs.

(and school district inservice programs)

(Spector, 1985)

Figure 3

2. organize information in courses incorporating S/T/S, i.e., using the structure of the discipline or current issues as organizers;

3. analyze existing school programs and course guides or syllabi for opportunities to infuse S/T/S;

4. establish criteria and procedures to analyze existing course activities to determine which of them ought to be modified to introduce S/T/S;

5. review and evaluate externally prepared curricular materials such as those presented elsewhere in this monograph;

6. evaluate the potential usefulness of resources including textbooks and other printed matter, media including computer programs, laboratory activity instructions, and tests;

7. establish and apply criteria to determine whether to adopt, adapt, or use available externally prepared curricular materials as a guide to design original activities and materials;

8. learn ways to identify and access community resources to use in teaching S/T/S; and

9. develop evaluation techniques to assess progress toward continuous course updating.

Examples of criteria that teachers could use to assess the appropriateness of the various forms of input for infusing S/T/S into precollege science courses include the following questions.

1. Does the input show application of scientific knowledge and skills and technology in the daily life of an individual while he/she enacts life roles as wage earner, family member, community citizen, and participant in recreation?

2. Does the input illustrate cause and effect relationships in contemporary problems?

3. Does the input emphasize the reciprocity between science and technology?

4. Does the input develop thinking skills?

5. Does the input show the ways science processes facilitate learning in other disciplines and, therefore, the interrelatedness of disciplines in real world situations?

6. Does the input apply values that underlie science, i.e., questioning all things, searching for data and meaning, demanding verification, respecting logic, and considering consequences?

7. Does the input provide insight into the role of science and technology in all careers of the future?

8. Does the input ensure fulfilling state and local education agency requirements?

Instructional designs for S/T/S teacher education programs should ensure that teacher participants acquire both S/T/S content, including the concepts in Figure 2, and instructional strategies and materials compatible with teaching S/T/S. S/T/S teacher education programs may range from one to two day district inservice workshops, to a three credit university course, to series of courses, to a cohesive master's degree program. The amount of time devoted to a teacher education program influences the degree to which teachers will develop the skills and knowledge base required to change their roles to include S/T/S in their science teaching.

PROGRAM FOR A MASTERS DEGREE IN SCIENCE EDUCATION WITH S/T/S EMPHASIS

The course titles and rationale that follow indicate the multiple dimensions required for a cohesive study of S/T/S that would enable teachers to infuse S/T/S in precollege science. Course titles are in parentheses and course abstracts are in Appendix B. The topics were derived from a study of an analysis of science teachers' roles and responsibilities for the eighties and beyond (Spector, 1984). The number of credits awarded and time allotted for learning experiences under each title will vary depending on local audiences, priorities, and resources.

Teachers need to understand the nature of the disciplines into which scientific and technological information is categorized (Current Topics in Basic Sciences). In addition to mastery of the basic science information in the existing body of knowledge, teachers need to be literate in the philosophical, historical, and sociological aspects of science and technology including the reciprocal influence between science and society and its educational implications (Science Education, the Meaning of Science and Technology and Their Interaction with Society).

It is essential that teachers emphasize that "science is doing" in contrast to the present emphasis on science as an already accrued body of knowledge. Therefore, one who teaches science to others needs to have first hand experience in "doing science" (Science Research Laboratory Mentorship and Designing Educational Research and Science Laboratory Research).

Once teachers know what to teach and understand why it should be taught, they need to determine instructional strategies that will best achieve these ends (What Research Says to the Science Teacher about Improving Instruction) and to select materials to support the instructional strategies selected (Futuring: Science Teaching Goals and Materials for the Eighties and Beyond). Laboratory experiences are a major part of the instructional design (Secondary Science Laboratory: Methods and Materials and Multidisciplinary Laboratory Instrumentation).

The expanded nature of the science teacher's tasks, the state-of-the-art in materials development, and effective instructional strategies require that teachers have linkages out of school in order to obtain resources from the community (Using Out-of-School Resources for Science Teaching). In light of the need to change science teaching from that which exists to that which is appropriate for future adults, schools need competent teachers with skills to lead systematic school improvement projects (Science Education Policy, Change, and School Improvement).

A strategy to retain high performing science teachers and attract highly competent new teachers is enhancing the professional status of classroom teachers (Spector, 1984). Change efforts need to be monitored and shared with the science education community to insure progress towards goals. When classroom teachers publish reports of successful practices they use, the reports are vehicles to obtain recognition, enhance teachers' images, and provide ways to contribute to improving professional practices throughout science teaching K-12 (Designing Educational Research and Science Laboratory Research and Science Teaching Thesis).

To maintain high quality in science classrooms, teachers need to continue studying throughout their careers and be able to guide their students in a career exploration process (Career and Life Planning for Science Teachers). Use of computers and audiovisual equipment is an integral part of all the courses in this program.

SUMMARY

Educating inservice science teachers regarding the interaction of science, technology, and society is a step toward mitigating the crisis in science teaching K-12. The nation cannot afford the luxury of waiting for undergraduate teacher training programs to be modified to focus on S/T/S and to produce adequate numbers of new science teachers capable of creating scientifically and technologically literate students. The existing cadre of teachers needs to change what is presently happening in science classes to make S/T/S an integral part of all students' formal learning in science K-12.

The likelihood of this happening can be increased if teacher education programs sponsored by school districts and universities address the following, to a degree commensurate with the time available for the program: (1) the legitimacy of teaching S/T/S, (2) the advantage to the teacher of teaching S/T/S, (3) S/T/S concepts and real world examples teachers need to learn, and (4) instructional strategies and materials compatible with S/T/S. This approach is intended to attract teachers and increase their commitment to S/T/S over time.

The optimal S/T/S education program for inservice science teachers is a master's degree program in which there is a blending of current basic science and technological information with the skills needed to integrate what is taught in the classroom and what is happening in the real world of science and technology. In experiencing work with research scientists, in developing a research project, in creating instructional goals and plans for systematic change, in using laboratories, in planning community involvement, and in developing lifelong plans for career development and professional growth, teachers will become capable, confident leaders in the process of changing the emphasis in precollege science to incorporate S/T/S and meet the needs of the eighties and beyond.

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APPENDIX A

I. Goal: Ascertain the meaning of science.

Objectives: The teacher will be able to

1. discuss perspectives on knowledge and knowing;
2. discuss science as the study of universal experiences;
3. discuss science as dogma;
4. discuss science as rationality;
5. explain a philosopher's description of science;
6. identify other "ways of knowing" including: aesthetics, philosophy, astrology, pseudoscience, parapsychology, remote viewing, precognition, religion;
7. identify the characteristics that delineate science from the "other ways of knowing";
8. compare science with other "ways of knowing";
9. use the creation/evolution debate to illustrate the difference and overlap between science and religion: issue of origin, devine origin, chemical origin;
10. explain the relationship between intuition (a hunch) and science;
11. describe the relationship of imagination and creativity to science;
12. discuss the limitations of science, the kinds of questions science can and cannot answer.

II. Goal: Describe the structure of science.

Objectives: The teacher will be able to

1. distinguish between observation, hypothesis, theory, model, law, and assumption;
2. explain the nature of scientific exploration;
3. explain the empirical nature of science - test hypotheses by experiment and observation after collecting data exactly, systematically, and objectively;

4. discuss criticism of induction and empiricism;
5. recognize the fundamental assumptions that underlie scientific work (causality, regularity);
6. explain the tentativeness of science "truth";
7. discuss the assumption that science is a strictly logical process;
8. discuss the role of objectivity in the scientist's attitude toward work;
9. illustrate the criteria that scientists use for judging the validity of knowledge in science (replicable and public);
10. distinguish between basic science, applied science, and technology;
11. delineate the parameters of science as an umbrella term for all the sciences.

III. Goal: Present a picture of the present and past relationship between science and the public.

Objectives: The teacher will be able to

1. illustrate social criticism of science and technology;
2. provide options as responses to the critics of science and technology;
3. describe situations in which the moral and ethical beliefs of the individual determine the way in which science and technology are applied;
4. discuss values in, and about, science as a source of strain for the individual and society;
5. respond with varied perspectives to the question, is it necessary to protect the public against science and technology?;
6. take both sides in a debate regarding the right to free inquiry;
7. discuss the controversy concerning controls versus non-controls over what basic research scientists should conduct;
8. discuss the controversy concerning controls versus non-controls over what applications technologists should be allowed to make using scientific advances;

9. use DNA research to illustrate the issues in debating the right to free inquiry;

10. write a scenario for "science on trial";

11. explain the politicization of science;

12. discuss the goals of science and the relationship to government support;

13. discuss the role of grants in research.

IV. Goal: Address a variety of science and technology related ethical considerations.

Objectives: The teacher will be able to

1. provide a variety of perspectives on the social responsibility of the scientist;

2. analyze the role and responsibilities of scientists in society today as compared to their role throughout history;

3. give examples where scientists have had positive and negative influences on societal decisions;

4. give examples where technologists have had positive and negative influences on societal decisions;

5. explain the effect of scientific secrecy on research results generated by scientists employed by private industry and/or government security research;

6. compare research science in a university or other public enterprise to private science;

7. relate applied and basic science differences to the issue of scientific secrecy;

8. project the practical and ethical problems surrounding scientific secrecy or openness.

V. Goal: Explain the educational implications for science instruction K-12 which are inherent in the nature of science, its meaning and structure.

Objectives: The teacher will be able to

1. give parameters for defining science education as a discipline;

2. compare and contrast the disciplines of science and science education;

3. describe various roles for science educators in society;

4. describe the educational implications of the reciprocal influence of science and technology;

5. discuss the history of science education in relation to the history of science and technology;

6. discuss the affective attributes of scientists and their relation to science teaching;

7. discuss the relevance of scientific fraud and falsification of data to science education;

8. discuss pseudoscience and its relationship to science education;

9. explain the way the uncertain identity of science affects science teaching;

10. relate the nature of scientific knowledge to liberal education;

11. support technological literacy as a goal for precollege science teaching.

VI. Goal: Discuss the historical aspects of science and technology.

Objectives: The teacher will be able to

1. present the development of the intellectual content of science;

2. recount the historical shifting of emphasis of scientific discovery away from Europe to the U.S.;

3. describe the current shift in emphasis of scientific discovery toward Europe and away from the U.S. and the reasons for the shift;

4. describe the scientists' view of science in society from an historical perspective;

5. describe views of the science/society relationship from an historical perspective;

6. delineate factors that influence the development of innovations;

7. trace the development of technology and its impact on society;

8. demonstrate the parallel to the major breakthroughs in the development of science;

9. become aware of the relationship between the development of science and our social history (social development);

10. give examples of seemingly unrelated science discoveries and developing technologies that contributed to major scientific breakthroughs in the past 50 years.

VII. Goal: Contribute to the growth of minorities in science and technology.

Objectives: The teacher will be able to

1. distinguish between issues that are common to all minorities and those that are unique to specific minorities;

2. identify the state of science education in minority institutions of higher education;

3. identify national, state, and local projects to enhance the position of minorities in science education;

4. introduce data from studies on social characteristics of minority college students, factors affecting science achievement of minority college students, and other related topics;

5. specify opportunities for grants, fellowships and scholarships for minority students;

6. describe the changing role of minorities in the history of science.

VIII. Goal: Contribute to the growth of women in science and technology.

Objectives: The teacher will be able to

1. identify issues that are unique to women;

2. identify national, state, and local projects to enhance the position of women in science education;

3. discuss issues related to the training and retention of women scientists and the special issues impacting on minority women;

4. specify opportunities for grants, fellowships and scholarships for women students;

5. describe the way women work in science;

6. delineate the professionalizing process for women in science;

7. identify where women get jobs in science;

8. describe the way women scientists are educated and trained.

IX. Goal: Describe the sociological aspects of science and technology.

Objectives: The teacher will be able to

1. analyze the impact of the accumulation of scientific and technological knowledge;
2. discuss "science as power" in an historical perspective;
3. describe science as a social force;
4. identify individuals and groups whose efforts, ideas or inventions have significantly affected the lives of other human beings, and describe their influences;
5. give examples of the way physical and biological resources serve as constraints which shape cultures;
6. explain and evaluate ways in which natural resources have been allocated, utilized and conserved in the community, region, the nation, and in other societies;
7. discuss relationships between specific rapid changes in technology and their impact upon society;
8. discuss the implications upon human existence of development of a technocracy;
9. explain and evaluate some effects of technology (e.g., inventions and methods of production) on the relationship between human beings and physical environment;
10. discuss the benefits and/or drawbacks of national technological progress;
11. discuss science as a human endeavor;
12. describe the interdependence of science, technology and the economy in terms of their processes, growth and development;
13. describe the effects of social, economic, governmental and societal actions on science and technology;
14. discuss the reciprocal influence between science and society

X. Goal: Explain the relationship of energy to science and technology.

Objectives: The teacher will be able to

1. analyze advantages and disadvantages of various energy technologies;
2. demonstrate the complexity of energy issues by describing systems which show the connections, mutuality and reciprocity of energy flows within natural systems;
3. discuss the effects of world demand and supply for energy;
4. discuss the relationship between the quality of contemporary life and the use of energy.

XI. Goal: Explain the interaction of science, technology, society, and science education effect the quality of life in the natural and human made environment.

Objectives: The teacher will be able to

1. apply biomedical developments to social and technological problems;
2. discuss attitudes which contribute toward living in harmony with the environment;
3. describe the effects the role of individuals have, both directly and indirectly, on the quality of the environment;
4. discuss science and technology creating new industries such as genetic engineering;
5. describe the impact of various industries on the environment;
6. describe the problems of industries which cause changes in natural environments and describe the social reactions to these changes;
7. cite examples of occupations that are primarily concerned with the study or control of specific environments;
8. identify non-governmental groups primarily concerned with environmental matters;
9. explain the effect of population growth on the quality of life (society);
10. predict the effects of economic changes on the environment;
11. predict the changes computer science will have on family life styles;

12. select an environmental problem, investigate alternative solutions to that problem, select one alternative and defend that selection.

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APPENDIX B

COURSE ABSTRACTS

1. Science Education, the Meaning of Science and Technology, and Their Interaction with Society provides the opportunity for teachers to explore underlying assumptions about science and technology that determined the contents of precollege science teaching to date and the assumptions upon which to build future directions for science. Teachers will learn to define science education as a discipline, to recognize that science education links science and society, to understand science educations relationship to science and technology, to understand the concepts and linkages that compose the content under the umbrella labeled S/T/S, and to make science relevant by using real world examples in their teaching.

2. Current Topics In Basic Sciences (Life Sciences, Physics, Chemistry, or Earth Science) addresses basic science concepts (in one of the preceding disciplines) that have been significantly modified or newly discovered in the past seven years. The criteria used to determine which topics and what detail to include are the Florida Standards of Excellence in Science, the Florida Minimum Standards in Science, and the Florida Framework for Science.

   At the outset of this course, degree participants will be given a description of the knowledge base, including background vocabulary and concepts needed to understand the current topics to be addressed. A variety of self-guided learning experiences will be available in a learning center for use by teachers who may need to review or acquire any portion of the knowledge base which will be assumed by the presenter.

   If the degree participant wishes to ask questions to clarify information in the learning activity package, a professor or a graduate assistant will be available at specified times to respond to such questions.

3. Science Laboratory Research Mentorship pairs a classroom teacher with a research scientist in the university or business and industry. This one to one relationship enables the teacher to obtain, first hand, personal experience with original laboratory research by participating in the daily activities of a practicing research scientist.

   This is necessary because degree candidates with full-time teaching obligations do not have the amount of flexibility of time required to do an original laboratory research investigation. This mentorship is a way to expose teachers to the realities of "science as doing" within the time available to them in a real world setting.

4. Futuring: Science Teaching Goals and Materials for the Eighties and Beyond assists the teacher to set the necessary parameters for instructional goals and to select materials to incorporate S/T/S. It

enables degree candidates to emulate teachers in the national programs of excellence who do not center their teaching on textbooks and do use a combination of materials from existing programs, teacher created work, books, media, and the community. Teachers review available S/T/S curricular material and learn procedures and criteria to evaluate all course inputs for their potential to facilitate infusing S/T/S including unconventional learning opportunities provided by the community.

5. What Research Says to the Science Teacher about Improving Instruction gives the guidance needed to determine appropriate teaching strategies to effectively and efficiently convey to precollege students the processes of investigation, knowledge such investigation provides, and the impact of such knowledge on the individual and society. (Implementation of practices reflecting current research in science education is expected to increase science learning at least thirty percent.)

6. Secondary Science Laboratory: Methods and Materials enhances the teacher's ability to provide students with appropriate science experiences through manipulation of materials and equipment to develop and apply skills for problem solving and critical thinking. Teachers will be trained to manage the laboratory safely, effectively, and efficiently, select appropriate activities, evaluate student performance, and devise logistics for sharing materials and equipment within a school. Proper use of a laboratory is a major instructional strategy required for teaching science.

7. Multidisciplinary Laboratory Instrumentation is a co-requisite with the preceding Secondary Science Laboratory: Methods and Materials course. This instrumentation course trains teachers to become skilled with a range of laboratory and field instruments and equipment likely to be available in well equipped secondary school laboratories. The physical and chemical principles on which the operation of the instruments are based and their appropriate use to extract specific types of information from the physical, chemical, and biological systems to which they are applied are included. Improvised instruments using simple components are constructed when feasible. Complex and expensive equipment used in research laboratories and in production control in industry are illustrated. The historical development of technologies that have facilitated progress in research is noted.

8. Using Out-of-School Resources for Teaching Science trains teachers to use the community as a resource including but not limited to building relationships with business/industry, government and civic organizations, the media, etc., and trains teachers to guide students to maximize use of out-of-school learning opportunities. The expanded nature of the teacher's task, the state of the art in materials development, and effective instructional strategies require the teacher to have linkages out of school to obtain the necessary resources (fiscal, human expertise, physical sites, instructional materials and equipment) from the community.

9. Science Education, Change, and School Improvement enables teachers to learn how change occurs in science programs in schools and ways to design interventions for planned change. In light of the need to change the context in which basic science is taught and the content and expectations for science taught K-12, schools need to embark on science improvement programs which require leadership from a science teacher in the school. Therefore, teachers need to be trained as internal change agents to improve the quality and quantity of science instruction K-12.

10. Designing Educational Research and Science Laboratory Research provides guidance in the design, implementation, and evaluation of educational research and science laboratory research, including: problem formulation and analysis, sample selection, instrument selection, formulation of research design and procedures, and data analysis. The relationship between educational research and science laboratory research is emphasized.

11. Science Teaching Thesis requires each teacher to design and implement a study which will contribute to the body of literature in science education and illustrate the teacher's ability to conduct science education research and use the results as a basis to redesign and improve science teaching. Conducting and reporting science education research is a vehicle to enhance the science teacher's professional image.

12. Career and Life Planning for Science Teachers enables them to become competent in planning for their own continuing education. Teacher education needs continue throughout a teacher's entire career. Needs do not cease with a university degree.

The career and life planning process enables teachers to use themselves and their own experiences to glean insights into ways to guide their students in a life-long process to gather information about vocational applications, to understand the role of science and technology in all careers of the future, and to explore opportunities for using science and technology.

CHAPTER 8

PROMOTING INTERDISCIPLINARY S/T/S APPROACHES TO SCIENCE TEACHER EDUCATION

Faith M. Hickman

INTRODUCTION

Scientific knowledge is currently growing at a rate of 13 percent a year. The World Future Society predicts that the rate of expansion will soon reach 30 percent annually. It takes only a little elementary arithmetic to derive the startling fact that the doubling time for scientific knowledge is only about three to six years. Even if the trend continues its relatively modest ascent of present rates, twice as much knowledge will be available in 1990 as today.

If this growth of knowledge were a mere accumulation of additional facts within existing knowledge structures, the growth might not seem so unmanageable. After all, if it were just a matter of knowing more about things that are already well understood, new knowledge could be accommodated within existing frameworks. But in science, accretion is seldom the norm. While the quantity of knowledge changes, so too does its character. Kuhn (1970) has pointed out how science changes through revolutions. Some of today's sacred axioms will undoubtedly go the way of humours, phlogiston, and spontaneous generation. For example, there was a time when the germ theory of disease was among the most hallowed and fundamental of all principles in biology. Now, its significance has diminished in light of new paradigms that stress the action of pathogens as merely one particular case in a wide range of gene-environment interactions that determine health and disease (Childs, 1978). Remember also that there was a time when Newtonian physics explained all conceivable properties of motion. Along came relativity and, while Newtonian principles remained useful, their limitations relegated them to secondary importance. That such revolutions continue today is inescapable. Consider, for example, recent challenges to the long-established link between salt consumption and hypertension (McCarron, et al., 1984).

The same thing happens with technology. The rate of change we experience in the application of scientific knowledge to everyday affairs must at least equal, if not exceed, the rate of scientific research. The first television broadcasts in the New York area in 1928, reaching 2,000 homes, elicited a modest fanfare--foretelling little of the dramatic impact that television was to assert on daily life a little over a generation later. Laser technology, which presently heals eyes and pinpoints military targets, was, in its earliest applications, little more than a curiosity. The practical application of Karl Landsteiner's discovery of blood types in 1900 escaped physicians for nearly three decades. Today, every person who has a blood transfusion or a transplant owes a debt to Landsteiner (Dixon, 1984).

What is the significance for educators of this rapidity of change in science and technology? What does a doubling of knowledge every three to five years mean for those who teach science in today's schools? What do changes in quantity and quality mean for the structure of curriculum and the education of teachers? Many answers are possible, but one fact is clear. The present structure of the curriculum--in which certain principles and facts are selected from a discipline as "important" for presentation to students--is inappropriate. One may, with comparative ease, specify what knowledge has been important in the past. One may even be able to capture some of the important facts and paradigms of today's science. But no one can expect to know what will be important even three to six years from now--much less in a decade or two. This means that our present approach to the construction of curriculum is woefully inappropriate, and new ways of structuring curriculum must be designed (Hickman, 1984).

It also means that traditional approaches to the education of science teachers are sadly lacking. Today, in many higher education settings, future teachers are crammed full of as many of the facts and principles of science as four or five years of training will hold. Then schools of education throw in a few "methods" courses on how to communicate these sacred facts and principles, resting assured that the science teacher is thus equipped to communicate what is "important" in science to hoards of eager children and teenagers. Never mind that many of those "facts" were obsolete before those expensive textbooks came off the press and before the ink was dry on the professor's lecture notes. Never mind that many of the facts and principles of science require formal operational cognitive abilities well beyond the capabilities of the vast majority of young people. Never mind that students and teachers alike have difficulty seeing what a formula for the acceleration of falling bodies has to do with their everyday lives. Never mind that our society is ham-strung by a host of moral, ethical, legal, and policy problems that--while rooted in science and technology--cannot be solved by either scientific or technological means. Never mind that today's students will be called upon to cope, as citizens, with an expansion of knowledge in science and capacity in technology so enormous as to defy human comprehension. Never mind that, if the world changes as much in the next thirty years as it has in the last thirty, that students will be living their middle years in a world unrecognizable to today's well-educated adult.

If giving teachers the facts of science and some techniques to use in presenting those facts is no longer appropriate, what is the alternative? None of us can know for sure, but there are some promising options. Today, we hear a great deal about the interaction of science, technology, and society (S/T/S). It has been suggested that S/T/S themes should dominate new curricula and new teacher education efforts. In simplest terms, S/T/S attempts to reduce the relative importance of facts for their own sake, focusing instead on the use of scientific knowledge to understand the real-world problems of today and tomorrow. Thus, the emphasis for students and teachers alike is less on the transmission of knowledge than on developing skill in its acquisition, synthesis, and application. If S/T/S education is done well, students should come away with some understandings that will carry them through uncertain times of rapid change. They will possess skills in thinking through problems that will serve them well as time goes on. They will know how to find and use the best and most up-to-date knowledge, instead of remaining mired in a bog of forgotten absurdities and half-articulated truths.

It is incumbent upon today's educators of science teachers to design and establish teacher education programs that equip both inservice and preservice teachers with the skills needed to work with learners in this way. This is admittedly a tall order, and nothing less than a decade of experimentation will undoubtedly be required for progress to become visible and widespread enough for impacts to be measured. Nevertheless, one must start somewhere, and some starts are being made in colleges and universities nationwide. Each of these efforts varies in form, purpose, and design. Nevertheless, each bears the mark of interdisciplinary, the fundamental premise of S/T/S and a critical conceptual element in the design of many new teacher education programs.

In this paper, the author will first examine some of the problems and potentials inherent in the interdisciplinary trend in the preparation and continuing education of science teachers and will conclude with a brief account of activities at the University of Colorado that are designed to promote school-community interaction for the improvement of science teaching.

THE TREND TOWARD INTERDISCIPLINARY INSTRUCTION

The science curriculum of the 1980s has been characterized by leaders in science education as human-centered, problem-based, and organized around issues of science, technology, and society (Hurd, et al., 1980; Harms and Yager, 1981; Bybee and Kahle, 1982; Bybee, 1982; NSF, 1980; Hickman, 1982; Hurd, 1982). As a result of this new curriculum, students in the future should benefit from instruction designed to promote in-depth examination of a host of multi-faceted questions ranging from the judicious use of genetic screening and counseling services (Scriver, et al., 1978) to citizen participation in the establishment of national policy (Holman and Dutton, 1978) on matters as diverse and difficult as the regulation of potentially hazardous research or the disposal of radioactive wastes. Experts in social studies and humanities education predict the same trends (Patrick and Remy, 1982; Koerner, 1981; Commission on the Humanities, 1980; Guidelines for Teaching Science-Related Social Issues, 1983), echoing the concerns of science educators about employment, health care, and citizenship in an increasingly technological world. Objectives for learning in the sciences will focus on the development of a synthetic (instead of reductionist) approach to understanding problems and making wise choices. That approach--which will emphasize the evaluation of options in light of consequences, risk-benefit projections and carefully articulated value positions--will soon become the *sine qua non* for effective teaching and learning in science (The National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983).

The plethora of recent reports on the improvement of education has highlighted the need for dramatic changes in the preservice and inservice education of teachers. With few exceptions, these reports have emphasized the need for interdisciplinarity in teaching, manifested through such tangibles as decreases in teacher specialization and increases in the diversity of instructional styles used in the classroom (Sizer, 1983). If such changes are to be effected, colleges and universities must take the lead, for it is there that virtually all preservice training--and a large part of the inservice training--actually occurs.

Unfortunately, teacher educators encounter a variety of major and minor difficulties in their attempts to design and implement programs that prepare teachers to manage interdisciplinary approaches. All involved--no matter how dedicated to the goals of a curriculum that crosses discipline boundaries--are likely to face at least ten general problems. These problems are reviewed below, along with some possible solutions.

> Problem 1: The complexity of issues of science and society. Understanding of interdisciplinary issues requires simultaneous attention to a host of conflicting variables. It is difficult to identify all the parts of a problem, much less to discern the multiple interconnections and to predict short-term and long-term consequences of alternative courses of action.
>
> Problem resolution: Science teachers in training need direct experience with analyzing "real-world" problems of science and society. Raw material for such analyses is readily available in newspapers, magazines, films, and professionally prepared curricular packages. Issues for study can be selected for relevance, timeliness, universality, and potential direct applications to the precollege classroom (Guidelines for Teaching Science-Related Social Issues, 1983). After analyzing issues themselves, teachers in training can develop their own units of instruction and engage precollege students in similar analytic processes.
>
> Problem 2: Problems in communicating across discipline boundaries. Each of the disciplines employs its own vocabulary, assumptions, rules of evidence, internal logic, external boundaries, and resultant world view. That's why the problem of the worldwide distribution of resources looks so different to an ecologist than to an economist or a theologian (Hardin, 1981)! Communication is elusive when such implicit differences are ignored or misunderstood.
>
> Problem resolution: Teachers in training need instruction on the history and philosophy of science in concert with similar instruction on the basic paradigms of other relevant disciplines--especially economics, ethics, political science, and psychology. The limitations of knowledge in the various disciplines should be stressed. The purpose should not be to make teachers experts in all disciplines. Such study should, instead, help teachers become comfortable enough with the character of the disciplines that they no longer fear searching out and using knowledge from different fields.
>
> Problem 3: Inaccurate views on what interdisciplinary teaching actually entails. Some teachers and teacher educators erroneously assume that interdisciplinary instruction requires expertise in all

fields (too much to master!) and the addition of volumes of new subject matter to an already over crowded school year (too much to cover!).

Problem resolution: Teacher education should involve teachers in the design and presentation of interdisciplinary lessons and units. Teachers should learn how to identify pertinent resource materials and collect data (both new and existing) from a variety of sources. "Scope and sequence" activities should show how interdisciplinary instruction can foster the same "basic skill" competencies as more traditional units. Teachers should learn how to match interdisciplinary activities to the goals and objectives typically found in the curriculum guides of schools and school districts. Simple techniques for managing personal lack of knowledge ("I don't know. How can we find out?") and for maximizing use of instructional time (small-group team work, meaningful homework assignments, field trips, speakers, mentorship situations for independent study, and so on) need to be stressed.

Problem 4: The professional image of the science teacher. Assuming that they will teach as they have been taught, new personnel may be drawn to science teaching by the order, predictability, security, and logic of the so-called "objective" sciences. It may be that the profession attracts individuals who, by virtue of their cognitive style and personal preferences, resist the ambiguity and tentativeness of the study of S/T/S topics and issues.

Problem resolution: Professional training for science teachers should demonstrate the depth of knowledge that the social sciences (and other disciplines) can bring to the study of science. Interdisciplinary studies do not abandon the rigor of science in favor of "mushy" opinion and unsubstantiated conjecture. Instead, the other disciplines contribute forms of investigative rigor and bodies of organized knowledge that strengthen, rather than weaken, the study of science. Interdisciplinary instruction is not less science. It is better science. Teachers in training can understand these points better after they have been personally involved in the investigation of prototypic issues of science, technology, and society.

Problem 5: Potential controversy about interdisciplinary topics. Although teachers report little fear of negative community response (Hickman, 1982), potential controversy is often perceived as an evil to be avoided if at all possible, perhaps because constructive ways of handling controversy have not been dealt with adequately in teacher education programs.

Problem resolution: Teachers in training need to learn specific techniques for anticipating and managing controversy, both in the classroom and in the community. Strategies for the community include discussing new units with administrators in advance, involving parents in curriculum planning and review committees, inviting people from the community to serve as expert advisors and speakers, and publicizing the goals of new programs at parents' nights and PTA meetings. Controversy in the classroom is effectively managed through careful selection of topics and resources, balanced representation of a variety of points of view, and analysis of the value dimensions that underlie differences in opinion (Hickman, 1984; Hickman, 1982; Hickman, 1985).

Problem 6: The structure of educational institutions. Both schools and colleges are organized around the disciplines for many practical purposes, including staffing, scheduling, and accountability. Distinct organizational lines usually separate the natural from the social sciences.

Problem resolution: Teachers in training need to learn about those barriers and how to surmount them. Team teaching is a promising alternative, as are cross-departmental committees for curriculum planning and evaluation. Teachers can also become advocates for innovative approaches to scheduling, assignment of classroom space, management of equipment and supplies, criteria for grading, and other administrative concerns (Hickman, 1984). Teachers in training can be taught (a) why such alterations are important; (b) what can be achieved through such measures; (c) how to work constructively and productively with the administration to bring about such changes; and (d) how to evaluate outcomes and redesign programs year-by-year. Colleges and universities can become models of interdisciplinary, cross-departmental collaboration by supporting integrative courses as a part of the core curriculum.

Problem 7: Confusion between subject matter questions and pedagogical questions. Teachers and curriculum planners sometimes obscure the objectives of interdisciplinary instruction by failing to distinguish "what to teach" from "how to teach." While it is true that independent investigations, small and large group discussions, critical readings and laboratory/field work are conducive to interdisciplinary instruction, more traditional lecture and recitation techniques may also be employed.

Problem resolution: Teachers in training need direct experience with a variety of instructional strategies. They should have opportunities to prepare and present material in several different forms--each aimed at the attainment of the same or similar objectives. Alternatives to textbook-dominated instruction need to be fully explored and their efficacy demonstrated through criterion-referenced evaluative techniques.

Problem 8: Difficulties in evalution. The desired outcomes of interdisciplinary instruction are thought to be hard to define and even harder to measure. However, assessments of student learning and of program effectiveness can be managed adequately through the use of extant evaluative tools and procedures.

Problem resolution: Although most teachers in training are exposed to Bloom's taxonomy of cognitive objectives, few actually gain experience in designing test items and procedures that address levels above recall and comprehension. Teachers need to learn how to write short essay questions that call for application, analysis, synthesis, and evaluation. They also need experience in constructing sets of criteria against which responses can be judged. They must also master the art of using non-pencil-paper kinds of measurement--including personal interviews, projects, investigative reports, oral reports, peer teaching, student self-evaluation, and others. The art of "subjective" judgment, i.e., drawing tentative but defensible conclusions from the evidence provided by student performance, needs to be mastered and employed more widely as an alternative to the tunnel-vision inflicted by so-called objective tests and letter grades.

Problem 9: The relative rarity of model programs. Few teachers have seen good interdisciplinary science programs in action, and fewer still have reviewed the curricular programs that are available for structuring such programs (Bybee, 1984).

Problem resolution: Teachers in training should review interdisciplinary curricular materials and should assess the potential of such materials for the improvement of their own practice. They should also learn about model programs that exist in their locales and should visit and observe if possible. Teacher training should also include discussion of the model programs that currently exist around the country, some of which are identified each year through the "Search for Excellence in Science Education" program of the National Science Teachers Association.

Problem 10: The lack of teacher-community interaction. Inservice teachers rarely enjoy sustained productive dialogue with other teachers, much less with individuals and organizations in the community that may have much to offer education. Interdisciplinarity in teaching and learning is hindered by the unavailability of a rich bank of knowledge, experience, and points of view.

Problem resolution: To ameliorate this situation, both inservice and preservice teachers need to learn how to identify and use resources both within and outside of the school. Techniques for making and using human contacts can and should be taught. Methods of assessing the utility of community resources must also be communicated to teachers. Finally, ongoing mechanisms for continuing expansion of the teacher's professional contacts must be initiated and maintained.

PROGRAMS AT THE UNIVERSITY OF COLORADO-BOULDER

It was in recognition of the need for interdisciplinary approaches to curriculum and teacher education that the University of Colorado-Boulder, in 1982, established the Center for Education in Science, Technology, and Society. The Center is an integral part of the School of Education and functions as a research and development unit serving the entire university. The staff, working committees, and boards of the Center address a variety of issues ranging from culturally-appropriate learning experiences for minority students to the common ground shared by science education and health education. The Center also works to promote collaboration between science teachers and history teachers in communicating the significant impacts that science and technology have exerted on the U.S. and the world. Members of the Center's staff teach inservice and preservice classes for teachers that attempt to overcome some of the difficulties outlined in the preceding section.

Of particular relevance to this paper is the work of the Center in establishing the Colorado Alliance for Science. The Alliance was specifically designed to address problem number 10--the lack of a mechanism for initiating and sustaining productive dialogue among teachers and others in the community. The Alliance is an important piece of the interdisciplinary, S/T/S effort, because it provides a means of expanding the teacher's horizon beyond the confines of a hard-cover textbook and four classroom walls. The world outside the school is inherently interdisciplinary. Bringing teachers into the community helps broaden views of the purposes and applications of what students learn in school.

The Alliance is a consortium of businesses, industries, schools, school districts, professional societies, research laboratories, government agencies and community groups. Alliance members share a common goal: the improvement of K-12 science education in Colorado. The four areas of activity for the Alliance are to (a) stimulate public interest in, and support for, science and science education; (b) address issues of public policy affecting the quantity and quality of science education received by Colorado's youth; (c) improve the support system for science teachers; and (d) increase access to, and use of, learning resources (Kennedy and Valletta, 1985).

The Alliance is now working on a number of fronts. One task force is assessing the needs of Colorado's minority youth, largely Hispanic and rural. Another is designing clearinghouse and extension services to serve teachers throughout Colorado. A third has established a system of bringing retired scientists and engineers into classrooms as volunteers. These volunteers serve as mentors for students' independent investigations and research projects. A fourth task force is planning ways to promote and expand school-industry partnerships in Colorado.

Another activity of the Alliance is its service as the coordinating and evaluating agency for the Hewlett-Packard Visiting Scientists Program. Currently operating in three northern Colorado communities, this school-industry partnership brings working scientists and engineers into a one-to-one collaborative relationship with science teachers. Teacher-scientist teams work together to develop new instructional materials, enrich the curriculum, and provide out-of-school learning experiences for students.

The Alliance also hosts meetings around the state to promote improvement of science education at the local level. During the 1984-85 academic year, the Alliance worked under a grant from Standard Oil of Ohio through the Institute for Educational Leadership to bring interdisciplinary, community action planning to Colorado's rural areas. Each year, the Alliance hosts a statewide meeting that brings teachers together with representatives of industry, business, higher education, school administration, and the research community. Participants in these annual events share ideas, discuss problems, and review progress.

The Alliance is also working with the Colorado Department of Education to plan curriculum development activities. New curricula in Colorado will be designed to serve both college-bound and non-college-bound students and will emphasize the achievement of scientific literacy through the study of S/T/S topics and themes.

CONCLUSION

Just as knowledge will continue to grow at astounding rates in the coming years, so too will the demands our society places on education in general--and science teachers in particular. There are no "quick fixes" for science education. No perfect system of teacher preparation and inservice education will ever be devised. It is only through sustained, widespread, intensive, and continuing efforts that the goals of improved interdisciplinary education will be achieved in the interest of our nation's youth. But, if the 1980s are to leave any positive imprint, visible results must be accomplished through a wide variety of ambitious, experimental, and continually re-evaluated efforts. Any less will cheat society, teachers, and the citizens of tomorrow.

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PART III

IMPLEMENTATION OF S/T/S: RESOURCES FOR CHANGE

CHAPTER 9

BUILDING S/T/S CURRICULUM: THE BSCS EXPERIENCE AND PERSPECTIVE

James D. Ellis

INTRODUCTION

Since its inception, the major goal of the Biological Sciences Curriculum Study (BSCS) has been to develop materials in the life sciences to educate citizens for participation in a society increasingly directed by science and technology. The BSCS was established as one education program of the American Institute of Biological Sciences (AIBS) with the objective to present biology "...in terms of the student citizen and what he must know to be able to lead a satisfactory and productive life" (Hurd, 1961, p. 136). During the first meeting of the BSCS steering committee, in February, 1959, the broad scope of the BSCS mission was clearly defined:

> It should be emphasized at the outset that the BSCS is concerned with biological education at all levels: elementary, secondary, collegiate, professional, and graduate. It is also interested in biological education outside the formal classroom situation: books, magazines, botanical gardens, museums, zoological gardens, television, and motion pictures. (BSCS 1959, p. 1-2)

The mission outlined by AIBS and the BSCS steering committee is reflected in almost 700 pieces of educational material in use in more than 50 percent of the school districts in the United States, and in more than 60 countries in adaptations in 20 languages.

The programs of BSCS are the result of several evolutionary stages of conceptualization that share the common goal of education for participation in society. During the first decade (1959-1968), the BSCS developed curricula based on the objective of science for living. The second decade (1969-1978) focused primarily on the concept of education for science and society. The theme of science, technology, and science was the basis for programs developed during 1979-1984.

SCIENCE FOR LIVING (1959-1968)

The first decade in the history of the BSCS was a time of rapid advantes in biology education. The BSCS was the focal point for those advances, concentrating first on developing innovative materials for biology education at the secondary level. Objectives for biology teaching established by the BSCS were to develop in students:

a. an understanding of man's own place in the scheme of nature; namely, that he is a living organism and has much in common with all living organisms;

b. an understanding of his own body; its structure and function;

c. an understanding of the diversity of life and of the interrelations of all creatures;

d. an understanding of what man presently knows and believes regarding the basic biological problems of evolution, development, and inheritance;

e. an understanding of the biological basis of many of the problems and procedures in medicine, public health, agriculture, and conservation;

f. an appreciation of the beauty, drama, and tragedy of the living world;

g. an understanding of the historical development and examples of some of the concepts of biology to show that these are dependent on the contemporary techniques, technology, and the nature of society;

h. an understanding of the nature of scientific inquiry; that science is an open-ended intellectual activity and what is presently "known" or believed as subject to "change without notice"; that the scientist in his work strives to be honest, exact, and part of a community devoted to the pursuit of truth; that his methods are increasingly exact and the procedures themselves are increasingly self-correcting (Moore, 1960, p. 2).

The BSCS began by developing educational materials in biology for secondary school students. Three programs were developed for the first high school biology courses. The following approaches were used to organize the content: the BSCS Green Version--an ecological approach; the BSCS Blue Version--a biochemical approach, and the BSCS Yellow Version--a more conventional cellular and organismic approach. Although the versions differed in approach, the BSCS agreed that each be designed according to the structure of biology shown in Figure 1.

The versions introduced the following important innovations in biology education: the content represented the current knowledge in biology rather than topics of historical importance; the focus was on how to do science rather than learning about science; the proportion of laboratory work was increased and a significant amount of that was open-ended; there was a thorough treatment of evolution and of human reproduction; and the first experimental editions contained no glossaries, a function of the attempt to reduce the number of technical terms. Reflection on those innovations often leads to the conclusion that the BSCS versions were designed for a special group of college-bound students. However, that is a contradiction of the intent of the BSCS, which was to prepare "a general education course in the biological sciences for all students entering the tenth grade" (Grobman 1969, p. 74).

Perhaps the contradiction exists in the developer's concept of "science for living." Although teachers were equally represented on the writing team, the team leaders, project directors, and steering committee members were mostly scientists. Not surprisingly, the BSCS concluded that an ideal biology program would represent the current nature of the discipline in content and process. The requirement of society at that time, as interpreted by the developers, was to educate students in an understanding of biology as a biologist understands it--therefore, providing society with a generation of citizens appropriately informed not only to participate in democratic duties but to fulfill the needs of national defense, scientific research, business, and industry.

However, the BSCS staff soon concluded that, although the green, blue, and yellow versions were excellent materials for academically able students, additional programs for special student populations were needed to meet the goal of providing quality education in the life sciences for all students. Therefore, during the first decade of the BSCS, projects were undertaken to provide materials for the academically unsuccessful student, the gifted student, and the educable mentally handicapped student.

Patterns and Processes provides teachers with instructional strategies for students who are academically unsuccessful for a variety of reasons, including below-average reading ability, inability to organize facts into conceptual wholes, and lack of interest in school facts. The BSCS second course, Biological Science: Introduction of Experiments and Ideas, is for students who have had a course in introductory biology and focuses on the process of scientific investigation rather than the body of biological knowledge. Me Now, and Me and My Environment, are sets of instructional materials dealing with topics in Life Science that are relevant to current and future populations of educable mentally handicapped pupils, ages 11-13 and 13-16 respectively.

Subsequent revisions of the green, yellow, blue BSCS versions have gradually increased the emphasis on human-related biologic issues. The steering committee recommended in 1965 that "the areas of human reproduction, the biology of human races, and population problems be included to a greater extent" (Grobman 1969, p. 46). In 1968, Dr. Bentley Glass suggested that biology curriculum emphasize the social aspects of biology and that the inherent problems be brought into the classroom. Dr. Grobman reflected that:

> The suggestion Dr. Glass made to the steering committee was a reflection of the winds of change that were beginning to affect curriculum development in the United States. Clearly the choice would be further liberalization of curriculum content and increased relevance to the lives of students. (Grobman 1969, p. 58)

SCIENCE AND SOCIETY (1969-1978)

During the second decade of the BSCS, the organization placed more emphasis on education in science and society. The preparation of the Guidelines for Development of a Life Sciences Program in the Middle School was the first BSCS project with a specific emphasis on science and society interrelationships:

> Human values and biological resources must be considered together if we are to assure the well-being of mankind. We seek, therefore, a new approach to the teaching of life science--new in rationale, purpose, and subject matter. We believe biological knowledge can be used to assess the nature of man, as well as to generate perspectives on personal and social problems related to own well-being. (BSCS Newsletter, 1969, p. 2)

Nine guidelines were developed that gave attention to changing concepts regarding the middle school as an institution, new points of view about the teaching of science, studies of adolescent development, research on learning and curriculum, and problems of teacher education. Guideline II stated the importance of including science-related social issues in the middle school curriculum:

> The proper science education for the emerging adolescent is one that connects general ideas from the biological and behavioral sciences with real problems and stresses their practical bearings. Our goal is to develop a population of young people whose biological enlightenment is related to social realities. (BSCS Newsletter, 1969, p. 5)

Because of the emphasis on science and society, the BSCS committee on biological science and society was formed in 1969. The committee held a conference dealing with biological science and society at the University of Colorado in Boulder during the summer of 1970. Several programs on science and society emanated from that committee. From 1970-1972 the BSCS developed paperbacks for a series on science and society including the following titles: The Personal Meaning of Birth Control; Science, The Brain, and Our Future; Human Heredity and Birth Defects; and Use and Misuse of Drugs Subject to Abuse. Another special project was the development of a nine-week environmental module, Investigating Your Environment. This program was designed as a holistic approach to environmental study where high school students conduct an investigation of the quality of the local environment through questions they have formulated based on their anticipated life-styles and values. Issue-oriented films such as "Tragedy of the Commons" and "Energy to Burn," and sound/slide programs on the social implications of scientific theory and discovery, such as "An Inquiry into the Origin of Man: Science and Religion" and "The New Genetics: Rights and Responsibilities," were also developed during this period.

Simultaneously with the activities of the committee on science and society, the BSCS committee on the life sciences that developed the aforementioned guidelines for the middle school continued its study and submitted to the National Science Foundation (NSF) a proposal to develop the Human Sciences Program (HSP). This seven-year project began in 1971 and culminated in 1978 with the publication of an innovative science curriculum for grades 6-8. The HSP project is one of the most thoroughly researched and carefully constructed programs developed by the BSCS. The program is developmentally based, designed to match the unique nature of the emerging adolescent, and can be further characterized as modular, activity-centered, interdisciplinary, and flexible. This new approach was developed in response to the enormous influence of changes in American life resulting from social crises, cultural disruptions, the changing image of science, and stress on schools. As Hurd (1978, p. 8) stated, "The new curriculum must not only have scientific validity but learner and cultural validity as well."

The Human Sciences Program which includes modules on Learning, Survival, Rules, Knowing, and Feeling Fit provides opportunities for interdisciplinary study of issues important to students. The goals of the program help students develop:

1. curiosity and motivation to study the natural and social worlds around them;
2. appreciation of science as a way of gaining knowledge about the natural and social worlds;
3. range of interests about and understandings of the natural and social worlds;
4. use of science process skills and logical thinking;
5. basic skills of reading and following written directions; communicating orally and in writing; and gathering, displaying, and interpreting quantitative data;
6. use of decision-making skills;
7. knowledge and acceptance of themselves; their bodies, minds, feelings, aptitudes, interests, and values;
8. self-esteem due to personal success in the program;
9. responsibility for their own learning; and
10. awareness that there are many modes of learning and sources of knowledge serving a variety of human purposes. (BSCS, Newsletter 1979, p. 5)

Concurrent with the development of the Human Sciences Program, the BSCS formed a committee to examine and later develop a K-6 science curriculum with a human perspective.

> It had been reported to the BSCS Steering Committee that many elementary school teachers, having observed how much student interest was generated in special education classes by the BSCS materials based on functions of the human body, were urging that similarly based materials be designed for their elementary classes. (BSCS Newsletter 1972 p. 11)

The resulting materials, the Elementary School Sciences Program, had as their goal to make process science in the elementary school more affordable both in purchasing the required materials and in training teachers to use the curriculum. The program is designed to accommodate limitations of the elementary school setting such as school budget, teacher background and motivation, and student characteristics and interest. The program is modularized and multidisciplinary and is a complete package with teacher's guide, student hardbound or softback text, equipment kit, media package, testing system, and ditto master worksheets. The general objectives of the program continue the theme of science for living. The activities of the program are planned and coordinated to:

> 1. promote interest, skills, and positive attitudes through experience with concepts in science;
>
> 2. challenge children individually at levels within their ability to respond effectively;
>
> 3. stimulate curiosity and elicit observation, analysis, achievable understandings and self-confidence, and a sense of responsibility to self and environment;
>
> 4. develop awareness that insights and knowledge can be applied to the tasks of everyday living (improving relations between self and environment). (BSCS Newsletter 1975, p. 1-2)

During the latter half of the 1970s, when science education focused on the relationship of science to society, the BSCS developed several other programs that deal with important social issues. Development of Energy and Society: Investigations in Decision Making began in 1974; the program was published in 1977. That program is innovative in its approach to energy education because it emphasizes controversial, value-laden issues and is one of the first BSCS curricula to incorporate decision making as a central, overt theme. The subsequent development of Investigating the Human Environment: LAND USE expanded the theme of educating students to make informed decisions about science-related social issues. The program focuses on the development of independent thought less affected by prejudice, and the development of a healthy skepticism. LAND USE is intended to sharpen the problem-solving skills that lead to thoughtful decisions. Quality of Life and the Future was developed in conjunction with LAND USE to investigate alternative solutions to issues important to future employment trends, population dynamics, and pollution.

The second decade of the BSCS can be summarized as a period of refinement of the rationale, goals, and development processes for education in science and society. Each of the BSCS programs for science and society contributed to a better understanding of the delimiters of such curricula. However, as times changed further refinements were needed to align the curricula with the requirements for living.

SCIENCE, TECHNOLOGY, AND SOCIETY (1979-1984)

As the BSCS began its third decade, goals for science education were expanded to include a study of the characteristics and dynamic interrelationships of science, technology, and society (S/T/S). The importance of including technology with the emphasis on society was reflected in discussions of the BSCS board of directors. Bentley Glass (1978, p. 3) suggested to the other board members that one theme should clearly be added to the other nine (see Figure 1): Theme 10: The social impact of science and technology. He continued by recommending, as a charter for future activities of the BSCS, a 1975 UNESCO statement from consultants to the United Nations Commission on Human Rights. Dr. Glass was one of six members of that consultant group which recommended the following:

1. The scientific and technological progress of mankind is an essential part of human, intellectual, spiritual, cultural, and moral advancement. What is necessary is to see the interconnection and interdependence between them, that is to say, the way in which each influences the other. Certain specific scientific and technological advances, such as those listed in paragraph 5 below, do pose risks to individual human rights, the welfare of society or the global condition of mankind.

2. Whereas scientific and technologic progress is a motive force in human advancement, the choice of values, objectives, and goals--in other words, the direction of advancement sought by a particular society at a particular time--is not inherent in the nature of science and technology. It derives largely from the emotional, cultural, and ethical aspects of human life. A true integration of scientific and technological progress in the life of a people, therefore, depends on the completeness of its mutual relationship with other intellectual, spiritual, cultural, and ethical standards and goals.

3. A thorough revision of education at all levels is required to bring about a sufficient harmony of science and technology with other human activities. Science and technology must be taught in the context of the ascent of man, not primarily as contributors to the disruption of society or the depersonalization of individual lives. A proper understanding of science and its impact on society is essential for dealing adequately with the evolving problems of civilization.

4. Not every change or development that science and technology make feasible needs to become an actuality. Governments and societies must determine by appropriate mechanisms for technological assessment--including the assessment of possible side effects and long-range effects--whether the time is right for particular innovations and whether their advantages outweigh for the society the discernible disadvantages. International machinery should be entrusted with such a technological assessment for mankind as a whole. It is a basic human right to have a voice in such decisions. Decisions in such matters must be made on the basis of the considered opinion of bodies of experts and laymen who represent the interests of all the people as well as future generations.

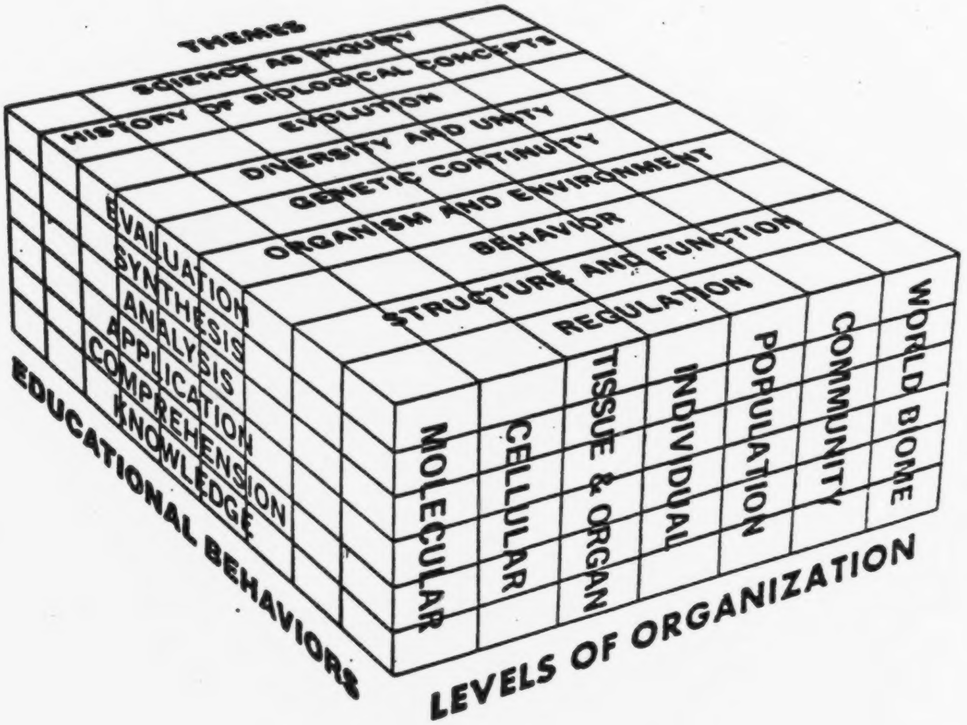
THEMES
SCIENCE AS INQUIRY
HISTORY OF BIOLOGICAL CONCEPTS
EVOLUTION
DIVERSITY AND UNITY
GENETIC CONTINUITY
ORGANISM AND ENVIRONMENT
BEHAVIOR
STRUCTURE AND FUNCTION
REGULATION
EVALUATION
SYNTHESIS
ANALYSIS
APPLICATION
COMPREHENSION
KNOWLEDGE
EDUCATIONAL BEHAVIORS
MOLECULAR
CELLULAR
TISSUE & ORGAN
INDIVIDUAL
POPULATION
COMMUNITY
WORLD BIOME
LEVELS OF ORGANIZATION

Figure 1

5. With these ideas in mind, and taking into account the necessity for keeping under constant review the promotion and protection of human rights in the light of rapid scientific and technological developments, the group recommends that consideration be given to the possibility of drafting a declaration on human rights and scientific and technological developments. Among the topics which would be covered by the declaration, the group recommends specifically the following: population planning (quantitative and qualitative) in relation to the right to found a family; protection against the hazards of the use of atomic energy; human experimentation; implications of new biological and medical discoveries (for example (a) tissue and organ transplantation and the use of artificial organs, (b) genetic manipulation of microbes, and (c) potential modifications of the human genome); the modification of mental processes by medical means; the social and ethical implications of the extension of life and of new definitions of and attitudes to death; and social and ethical choices in relation to equality in the provision of health protection and medical care.

6. It is recommended that a better definition be given of the duties of the individual to the community and of the rights of future generations. For example, it seems to us that the crisis in growth of the world's population must lead to some constraint on the individual right to reproduce, and that the right of the child to be born physically and mentally sound takes precedence over the rights of parents to reproduce. (Glass, 1978, p. 4)

Other BSCS board members delineated the meaning of education in S/T/S. Hurd (1978) explained that "the distinctions made between science and technology are no longer real. Science and technology have become broadly integrated into a complementary endeavor, each dependent upon the other for the production of new knowledge." With that concept of science and technology Hurd proposed to the BSCS a new context for the teaching of biology that would:

1. be taught in a social and human context, perhaps as a science of human beings;

2. include values and ethics as goals, recognizing that there are moral and aesthetic as well as scientific answers to human problems;

3. have courses organized more according to biosocial events and problems that have meaning for the quality of life, rather than according to the logic of biological disciplines;

4. consist of subject matter selected for its task, action and applied values that can serve real life and practical ends;

5. be taught from a holistic and integrative point of view with a curriculum that is transdisciplinary in concept and structure;

6. make sure that a substantial fraction of laboratory investigations include individual and community-based problems, issues, and policies;

7. encourage additional cognitive skills, such as decision making, valuing processes, knowledge-validation, problem resolution, concept of risk, and ecological thinking;

8. orient biology teaching toward the future, giving students opportunities to consider various alternatives for the future course of human efforts;

9. use more individualized and personalized teaching to accommodate established learning styles of different students as well as different learning needs; and

10. recognize that the biology teacher is an interpreter of biology concepts, theories, and research, and serves as the intermediary between scientists and the lay public. (Hurd, 1978, p. 25)

Two major BSCS projects completed during this period focused on the theme of science, technology, and society. The human genetics project had its roots in the Guidelines for Development of a Life Sciences Program in the Middle School that had incorporated the study of humans as biological organisms as one of its major themes. Those guidelines were an early mandate to develop curricula on human biology. A 1976 study by the BSCS supported by the National Foundation - March of Dimes developed Guidelines for Educational Priorities and Curricular Innovations in the Areas of Human and Medical Genetics. During this period, the BSCS staff investigated education in human genetics. The staff conducted needs assessment surveys and sponsored a symposium titled "Human Biology: A Key to Scientific Literacy." In 1979, work began on the first human genetics material for grades K-12.

Basic Genetics: A Human Approach is a high school level program that explores a wide variety of genetic-related issues and focuses on students as individuals and on their parents, their relatives, and the children they may have some day. The use of the human organism as a model provides the benefits of presenting applied biology. Genes and Surroundings, a program for the junior high/middle school, focuses on human genetics as the science of human variability--its origin and its implications. Nowhere is that variability more evident than during adolescence. The materials have been designed to accommodate a wide range of cognitive skills and emotional development. You, Me, and Others, a program for grades K-6, examines human genetics from the perspectives of variability, change, and continuity. Students are asked to observe, record, and interpret the variability that surrounds them.

Innovations: The Social Consequences of Science and Technology Program (IST) was the second BSCS project completed during this period. IST is the first BSCS project with an emphasis on technology-related social issues. Previous projects, such as the human genetics programs, included technology issues to a lesser extent. IST provides senior high school and beginning college students with opportunities to explore recent scientific and technological innovations and their social consequences. The project was funded in 1979 by the NSF and five modules were published in 1983. The following titles are included in the program. Science, Technology, and Society (an introductory module); Television; Computers and Privacy; Biomedical Technology; and Human Reproduction: Social and Technological Aspects.

Each module in the program attempts to answer, with varying degrees of emphasis, five organizing questions about the technology under consideration: What is it? (How does it work?); How does it affect me?; How does it affect us?; How valuable to us is it?; and What might be its future? In some instances, the students will collect information and data outside the school by visiting commercial and public television stations, conducting surveys, using public libraries, and conferring with individuals or members of organizations in the community. These innovative materials are meant to be models of curricula for education in science, technology, and society. Future BSCS projects will build upon the experience gained through the development of those materials and will design more complete curricula for all levels.

BIOLOGY EDUCATION FOR THE FUTURE

The BSCS has survived a time of change and upheaval in science education. The BSCS mission--the development and testing of curriculum materials for the purpose of advancing scientific literacy and improving education in the sciences--remains the same. However, the BSCS is redirecting its attention from past achievements and projects to a focus on new perspectives in biology education. The BSCS is currently involved in a study of educational projects for students who will contribute to the twenty-first century.

Two major BSCS projects are directed at education in the life sciences for the future. In September 1983 the BSCS began development of a K-8 health education project. The rationale and need for Making Healthy Decisions were established through several years of intensive study that originated with the 1977 BSCS symposium on new directions in human genetics and health education. Making Healthy Decisions is an interdisciplinary health education curriculum that emphasizes individual responsibility for health, improved health decision making, and attitudinal and behavioral change regarding health-promoting lifestyles. The program is unique because it bases objectives for classroom activities on personal behaviors that promote health and prevent disease. The experimental materials for grades 6-8 were prepared during the summer 1984 and were field tested with more than 1,500 students in Colorado schools during the 1984-1985 school year. Materials for grades K-5 will be developed and revised during later years of the project. The project will culminate with a full year of implementation and evaulation during the 1988-1989 school year.

The second major project of the BSCS during this time period will be to develop an approach to education in the life sciences that emphasizes human biology. The BSCS sponsored a symposium to study the role of biology in education in conjunction with its November 1983 board of directors meeting. The BSCS board, representatives from selected professional biological societies, and other distinguished guests met to discuss the implications for biology education of the various reports on the status of education in the United States. One point of discussion was the conspicuous absence of biologists on the committees studying science education and the resulting lack of emphasis in the reports of those committees on the role of biology as a major force in American culture. The following five guidelines for biology education were identified by participants (BSCS, 1984b) in the BSCS symposium:

1. The Place of Biology in General Education. The teaching of biological sciences should promote the development of scientific and technologic literacy and associated intellectual skills. (p. 5)

2. The Orientation of Biology Education. The teaching in biological sciences should be oriented toward a human and social perspective. (p. 7)

3. The Role of the School Life Science Teacher. Strategies to improve biology education should recognize the importance of the classroom teacher. (p. 10)

4. The Role of the Universities. Improvement in the quality of biology education must begin with improvements in higher education, particularly in institutions that train teachers. (p. 11)

5. The Educational Environment. Proposals to improve biology education should include a realistic assessment of the total educational environment and systematically plan for short- and long-term changes. (p. 13)

After careful deliberation, the BSCS Board of Directors has directed that the development of a human biology program (as yet untitled) for the secondary school will constitute the future direction of BSCS. The shift to a biology curriculum with a human perspective does not represent a knee-jerk response to the recent crisis in science education. Rather, it reflects more than a 25-year evolution of a concept of biology education that is aligned with a reality of the times--a process described by Barufaldi. (1977, p. 1)

We have now entered an era when science and technology control the tides of human events. Society has become dependent on science and technology to maintain the global economy. Science and technology are dependent on one another to maintain the level of productivity of knowledge and control:

> The biological sciences have become a major force in American culture. Biotechnology and biomedical research have spawned new prospects for improving health, extending life, and assuring ample

> supplies of food for a growing segment of the world's people. Many of those advances raise new questions that call for new ethical judgment and for informed participation in the development of new social and public policies. These developments suggest the need for a reform in biology education to close the gap between what the public knows and understands and the status of research in the life sciences and its impact on human affairs. (BSCS, 1984b, p. 2)

Therefore, the BSCS will first meet that need by developing a biology program for the secondary school that presents the science and technological content from a human perspective and deals with social issues designed to prepare students to cope with the future. Hurd (1982) has summarized this approach:

> What then is the new biology for life and living all about? It is a biology that honors human nature and the character of human culture and that recognizes the cognitive potential of human beings. It is a biology designed to increase the adaptive power of the individual and help assure a favorable evolution of human beings not simply to exist, but to attain an ever richer quality of life. (p. 8)

THE CHALLENGE TO CURRICULUM DEVELOPMENT

The BSCS is faced with the challenge of developing educational materials appropriate for the next 25 years. Many similarities exist between the realities of the present and 25 years ago. They are that:

1. Scientists, politicians, parents, and educators agree that a crisis exists in science education.

2. Education in science, technology, and mathematics is held as a basic requirement in our schools.

3. The current curricula in science no longer adequately prepare students to participate fully in society.

4. Improvement must be made in our educational system to ensure the welfare of the nation.

However, are the times so similar? The response to the Sputnik crisis was similar to a wartime effort to defend our nation. Our national resources were mobilized and committed to improving education. Is such a response to the current crisis visible? The major changes in the biology curricula that occurred 25 years ago were the updating of the scientific content and the attempt to present the inquiry processes of science. These changes required that teachers update their knowledge of science and conduct more laboratories in their instruction. However, today's crisis calls for a more pervasive realignment of science education. Reports analyzing the current crisis suggest the incorporation of technological concepts and achievements into the science curriculum. They indicate using human values, social issues, and decision making as central themes in the biology curriculum. How many biology teachers have experiences and training to deal with those requirements?

BSCS programs continue to meet the challenge. Experimental materials in S/T/S have been developed and tested during the past 15 years. The BSCS process of curriculum development has been expanded and refined to facilitate development of those curricula. New criteria for defining objectives include:

1. using needs assessment surveys of students, parents, and educators to identify important social issues in science and technology;
2. using important political issues in science and technology as one focus for secondary science education;
3. using issues important to adolescents as the focus of a middle school program; and
4. using behaviors rather than content as the focus of a health curriculum.

The major success of the BSCS during the past 10 years has been the development of models for education in S/T/S. The BSCS projects during that time have conceptualized the goals for education in S/T/S, enhanced awareness among leaders in science education about S/T/S, and demonstrated new models of teaching appropriate for S/T/S. The S/T/S programs at BSCS have been teacher tested and thoroughly evaluated. The following attributes have been determined to be important for developing S/T/S materials:

1. developers should include professionals from the social sciences, sciences, humanities, and education such as: cultural anthropologists, social psychologists, developmental psychologists, bioengineers, philosophers, historians, health scientists, science educators, and specialists in curriculum development, reading, and learning;
2. materials should be tested and evaluated by teachers and students in realistic situations;
3. parents and other members of the community should be involved in all phases of the curriculum development process, especially in the implementation of the curriculum in local settings;
4. activities should be open-ended with suggestions for further investigation included in the materials;
5. data for activities should be gathered by the students from their social/biological environment;
6. the teacher's guide should be detailed and prescriptive and provide the following information:

   - rationale,
   - objectives,

- background information,
- strategies for teaching the activities,
- explanation of teaching techniques,
- suggestions for dealing with controversial issues,
- suggestions for working with parents and other members of the community, and
- suggestions for integrating the material into existing objectives and activities; and

7. teachers should be trained to use the materials.

It is important to note that the new BSCS materials based upon that approach to science education have not been received with the enthusiasm of the materials developed under the rationale of 25 years ago. Only a few thousand students have used the BSCS programs. Large commercial publishers have been unwilling to risk publishing materials that are not in the mainstream of science education and fear that the content of S/T/S programs and the packaging of the materials as single topic modules lack commercial potential. Most science teachers have not adopted the S/T/S perspective. Only those teachers already disciples of the S/T/S approach seek out the BSCS programs. Nonetheless, as McInerney (1985) points out:

> The task of combating ignorance and ensuring informed participation falls to all of us...Today, science educators have an additional burden, because the knowledge we command and transmit to our students contains the seeds of potential enslavement, even destruction, if misused. (1985)

The conditions of 1959 are not those of today. Educators have been more involved in the reform movement than previously, when scientists led the reform. However, the educational bureaucracy is not as naive as before. Many teachers and administrators have grown skeptical of educational reform. Last time the reform was a surprise, and fervor was quickly developed among teachers and administrators. Have we reached the critical mass of dissatisfaction that will encourage educators to sacrifice to make a substantial change in practice?

There are several philosophical and organizational barriers to the development and implementation of S/T/S curricula. The philosophical barriers include lack of awareness, understanding, and acceptance of the rationale for S/T/S; and the discomfort of educational practitioners and parents with the content and teaching strategies. One organizational barrier is the lack of national, state, and local preservice and inservice training programs incorporating S/T/S for educators. Another organizational barrier involves the lack of an infrastructure to support innovation. Many states do not have a science supervisor to help local districts with innovation, and most school districts provide little incentive and assistance to innovative teachers.

Some state policies concerning textbook adoption hinder innovation by requiring science curricula eligible for support by state funds to be comprehensive programs in predetermined subjects such as biology, physics, and chemistry, that are published as textbooks. That policy requirement precludes adoption of softbound modules on focused topics. The policy is counterproductive to producing materials in S/T/S where issues change rapidly. The cycle for revision of S/T/S materials must be much abbreviated to ensure the relevance of the issues. Curriculum developers must attend to what has been learned about education in S/T/S from the development and use of the BSCS S/T/S programs.

CONCLUSION

The BSCS has been developing and evaluating education in S/T/S for more than a decade, culminating with the 1983 BSCS symposium on biology education. That study has yielded successes and failures and identified barriers to innovation described in this paper. Therefore, the following projects are suggested to further investigate education in S/T/S:

1. revise preservice and inservice teacher training programs and incorporate S/T/S in the science courses and methods courses;

2. research models for S/T/S that emphasize:

   - procedures to increase community support and involvement,
   - effective teaching techniques for S/T/S, and
   - methods to disseminate S/T/S material based on short-lived, current social issues;

3. develop complete science programs that:

   - fit into the existing organizational structure of schools,
   - integrate science- and technology-related social issues into the curriculum,
   - expand teaching techniques, and
   - include implementation of dissemination programs as part of the development package; and

4. involve the private sector in designing, disseminating, and implementing the product.

Two actions must be taken if the current crisis in science education is to result in significant improvements in the education of our nation's youth.

1. Parents, teachers, administrators, scientists, social scientists, teacher educators, curriculum developers, and politicians must unite and effect a collaborative effort with the single goal to educate our nation to function in the scientific and technologically-based society.

2. Effective science curriculum with a human perspective for life and living must be developed and implemented.

The BSCS invites all educators to join in meeting the challenge of providing an appropriate education for the future stewards of the world.

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CHAPTER 10

S/T/S: A CURRICULUM FOCUS THAT WORKS AND AN OVERVIEW OF SELECTED PROGRAMS

John E. Penick

INTRODUCTION

The advent of the National Science Foundation curriculum projects of the 50s and 60s gave technology and the applications of science a back seat to the processes, explorations, and content of science. In the late 60s, the environmental movement began and was given considerable boost by the fuel shortages of the 1970s. Educators realized the need to include in their programs societal issues, applications of science, and wise uses of technology in society. With time, educators, students, and community leaders demanded that energy, populations, environmental quality, and the effects of technology be integral parts of the curriculum.

Concerned teachers and curriculum developers responded with teaching units focusing on values, ethics, human engineering, and social perspectives. Enlightened teachers inserted these units in various places in their science and social studies curricula and several complete curriculum projects focusing on Science/Technology/Society (S/T/S) were developed. But, even in 1985, it is safe to say that the S/T/S curriculum is not yet a prominent feature of schools in the United States.

The Project Synthesis group (Harms and Yager, 1981) realized this when they published their analysis and recommendations for S/T/S programs. They felt many specific areas for concern related to societal issues in science and technology and emphasized hard and soft technologies and their impact on society. The Synthesis researchers had definite outcomes and desires in mind. They wanted students to recognize and practice energy conservation, knowing what trade-offs they must make. They wanted students to identify and solve problems related to science and society. They felt strongly that students should know population control strategies and recognize family planning as an active part of it, and they encouraged students to seek careers in science and science related fields other than those traditionally emphasized in high school science classrooms. Many of these careers involve using technology, or at least understanding how it is used. They hoped that S/T/S curriculum would take advantage of careers and social concerns by placing them as integral parts of the science curriculum. Today, commercially available S/T/S materials can be purchased and one can observe functioning models of excellent, locally developed S/T/S programs.

LOCALLY DEVELOPED AND EXCELLENCE

Using criteria from Project Synthesis, the National Science Teachers Association in 1982 began a Search for Excellence (Penick and Yager, 1983) among programs designed to emphasize S/T/S in the science classrooms. The ten programs identified by NSTA are very different from each other and very different from the traditional school science offering. What these programs do have in common is that they tend to be activity-oriented, locally developed curricula designed as complete courses in S/T/S. They focus on energy, population, environmental quality, natural resources, and the sociology of science. They make S/T/S careers known and study issues, not just answers.

Students in these programs, however, are doing far more than studying; they are taking action as well. Students have testified at hearings, written many letters to editors, gone to court and developed a keen awareness of not only the problems that exist, but also the solutions; and that these human solutions may lead to additional problems.

LOCALLY DEVELOPED S/T/S PROGRAMS

At Sheehan High School in Wallingford, Connecticut, students study all the classical notions of energy and energy use but go considerably further. Many of these students prepare to take the state energy auditor certification test, enabling them to do energy audits. In the first year of their program, this class of students conducted an audit of buildings in their own school district. Based on this audit, recommendations were made and changes in buildings, energy uses, and awareness came about. A result was the district saved $260,000 in energy costs in the first year alone. Perhaps school is the real world after all!

Perhaps not as spectacular, but having an equally strong impact on students is the program at Kelley Walsh High School in Casper, Wyoming. Here, students study energy from many perspectives. They analyze power plants and their locations, studying inter-energy transformations while questioning need, necessity, and profit. These students study other energy transformations in manufacturing, packaging, and transporting materials. They question the use of nature resources and probe into government subsidies. Looking at issues, legislation, and ideas leads them to develop a very personal awareness of energy and energy consumption. And, all the processes of scientific investigation are present, necessary, and practiced.

These students also take action on issues and have been active at the city, state, and national level. Students from this program have testified at senate hearings, provided input to the city council, and written many persuasive documents. These students are learning not just about personal and public energy consumption, they are learning how the legislative process works, how change occurs, and how they as individuals can make a difference.

Also focusing on energy, the solar projects class in Toledo, Oregon, has students designing solar efficient housing. These students work with interior and exterior design, insulation, energy efficiency, and aesthetics. But most unique of all is the direct tie-in with the home construction class of that high school. Not only do students research the design of solar efficient homes, they observe the construction and sale of the house, and see their neighbors living in a home they designed for solar energy efficiency. This is another example of a school providing more than a practice environment for life.

Two New York programs have focused almost exclusively on the human aspects of science. Mankind: A Biological/Social View, developed at Clarkstown South High School in West Nyack, New York, combines human ecology and anthropology in one course. Students study man and animals in society, culture, and environment. This issue-oriented program uses a variety of kits and an extensive reading list. Students learn to draw parallels between humans and animals, their development, and their interactions. In the process, students come to understand and appreciate better their own society and environment. Students learn that they have both a culture and a place in it. In essence, students are learning to apply the techniques, tools, and analytical processes of science to the study of themselves and mankind. In looking inward, they can't help but question the values and issues raised within society.

Contemporary Issues in Science, at Susan Wagner High School, Staten Island, New York, is a program designed to be a complete elective course in science or social studies or a series of units to enrich existing courses. Major components of discussion, research, lecture, and forum deal with science-related social issues. A variety of guest lecturers present numerous topics while, at the forum, students share ideas with community members in business, academia, and government for a full day each semester. Considerable real-world problem solving occurs.

In Wausau, Wisconsin, teachers developed their own two-year, unified science program. This two-year program, replacing general science and biology, focuses on societal issues using the classical inquiry processes of science for resolution. With their modular schedule, students have three sizes of classes each week. In these classes, content is the vehicle rather than an end to itself. Instead, students seek data, make interpretations, and draw conclusions within the cultural confines with which they are familiar. This team-taught program has considerable flexibility and introduces students to issues and ideas rather than mere facts and concepts. Students come to recognize that issues are a beginning, that resolution is a midpoint, and that action is the most desirable end product.

In a similar way, the elementary students at Monte Sano Elementary School in Huntsville, Alabama, seek solutions to real world problems in small groups. These students study local ecology, animals, and the natural resources of Alabama. Their study includes archaeology, cemeteries, and classical plant and animal studies. This non-text program, correlated with their social studies, leads students to recognize early the interrelationship between science and society. Theses students are going to grow up feeling that science is a human activity and that the many problems of nature are a result of man's interference and lack of understanding.

This same understanding is emphasized in the environmental program at Quilcene Junior High School, Quilcene, Washington, where 7th graders study energy cycles in a marine environment. They hatch fish eggs for release and monitor water quality for the Forest Service. Students gain considerable exposure to careers in science and science-related fields while gaining expertise and confidence in using technology for environmental monitoring. In the process, many issues arise. Where to release fish? How many should be released? What affects water quality? What can we do about it? These students are ready and eager for action to improve and maintain their environment.

The Gompers Secondary Center, a magnet school for math, science, and computers in San Diego, California has taken a different approach. This magnet school, with one computer for every ten students, emphasized computers and calculators as tools in math, science, and language classes. All students complete an experimental design course in ninth grade and then two years of science in grades ten through twelve. Most students take three years of science in which computers and calculators are integral parts. These students are using technology, not just studying it. They are actively involved in simulations as well, learning the power of computers as tools and as motivating devices. These students are seeing directly the effects of technology on their own lives and learning.

None of these schools view their programs as final. They see themselves as involving, changing, and growing as the needs require. They do not view themselves as dependent on technology but as users of technology. They are analyzing issues but are not content to stop there. They insist that students take action and find more information on their own.

Also unusual, developers of these innovative curricula do not view their written materials as "the curriculum." To them the curriculum is the total and dynamic interaction of those materials with students in an appropriate and intellectually free atmosphere. They know full well that such an atmosphere is created by teachers using carefully designed teaching strategies in classrooms arranged and decorated to enhance learning through science. Much emphasis is placed on students, and it works.

Students in these programs are finding that they do make a difference. They are learning ways of gathering information, analyzing that information, and communicating results. Students are developing techniques for bringing about change rather than merely talking about changes that might be made.

These students in many ways are getting the education of the future, today. More programs such as these could make a considerable impact and difference on student attitudes, and, ultimately, their involvement in science and science related careers, social issues, and actions. These are citizens we want and need.

COMMERCIALLY AVAILABLE S/T/S MATERIALS

While a variety of materials are available, none fully meet the definition of "a curriculum" as meant by developers of innovative programs. Still, these commercially available materials do offer useful and convenient activities for the science classroom when teachers with ingenuity use them in conjunction with other materials and appropriate teaching and evaluation strategies.

Designed for high ability students in the upper secondary grades, Science in Society (1981) supplements the science curriculum. Booklets and projects present students with controversial topics emphasizing the field of applied science. Activities range from third-world health issues to farms to "Cooking Peas."

In all activities, students investigate a topic, use their knowledge of science, accumulate more knowledge, and make decisions leading to action on the topic. As they study, students learn of careers, resources, and ideas not normally found in the science classroom.

While ISIS (Individualized Science Instructional System, 1978-1981) was not designed specifically as an S/T/S program, many of the modules feature applications of science and careers. Units such as "Kitchen Chemistry," "Know Your Car," and the "Physics of Sport" all ask students to investigate, apply, and understand how science affects their own lives. Such S/T/S units can easily supplement any curriculum or may be used with others to replace many existing curricula. Science Technology and Society: BSCS Series (1984), a one-semester interdisciplinary series, integrates S/T/S with the science curriculum. Modular in nature, the program focuses on educating the general citizenry regarding issues of S/T/S having important consequences for the future.

Science and Technology (1985) focuses on science literacy for elementary students with easy reading, S/T/S issues and questions, and relevancy. Technological education and its significance are vital components of modern science and integral parts of these written materials.

Science and Social Issues (1983) allows students to investigate critical issues with S/T/S components. Ultimately, students take positions and action, using their findings for support. Designed for average high school students, issues and units provide curriculum supplements relating to issues which face us today.

Values and Biology (1983), sixty-eight classroom activities involving controversial issues, presents a working guide for introducing bioethical issues. Offering teaching strategies as well, each chapter has a topical issue, ethical questions to consider, student activities, and resources.

Developed by a unit of the United Nations, Model Teaching Units for Primary, Secondary, and Teacher Education (1983) consist of twenty-six teaching units dealing with world concerns. Students are to develop an understanding of the impact these concerns on peoples' lives by focusing on the world as a community while investigating a number of global concerns.

From a different perspective, that of teacher education, Science and Society (1984) incorporates S/T/S themes in a methods text organized around three major teacher-student transactions, listening-speaking, reading-writing, and watching-doing. The book stresses human identity, organization, interaction, change, limitations, and conservation.

SOME FINAL THOUGHTS

A curriculum reflecting S/T/S issues is not a new idea. But, while elements have been with us for some time, only recently has the movement truly taken a form of its own. Now, with both commercially written materials and exemplary working models, the S/T/S curriculum is finally on its way.

As more and more teachers insert S/T/S ideas and strategies into their teaching, they are discovering that students are interested, traditional topics are still necessary and covered, and teaching becomes more enjoyable. Curriculum should be like all other ideas, strategies, and products; it should continually evolve as we gain more understanding and information.

It is this evolution which has produced the exemplary programs which are characterized by continued change. School science and teacher education programs can easily change to incorporate and reflect ideas presented by these materials and exemplars. As S/T/S ingredients are added, one finds more everyday science, science useful to students now and in the future.

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CHAPTER 11

AGENDA FOR ACTION: S/T/S IMPLEMENTATION

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INTRODUCTION

In the last quarter century science education has made a complete cycle from one crisis to the next. Federal dollars were expended throughout the 1960s and early 1970s in relatively large amounts in order to accelerate this country's supremacy in the space race through the education of young people in science and the application of technology to numerous problems and issues. Curricula were developed and teachers were prepared in order to implement new programs and materials. But 25 years later most data and opinions support the conclusion that we're back to" square one" and science education is again said to be in a crisis. What happened?

Considerable money was spent but the problem persisted. Many concluded that the methods and products were wrong. The authors believe that the "failure" of the 1960s curriculum reform movement was not necessarily a mistaken choice of direction or approach to the teaching of science, as much as it was a failure to implement these programs. NSF's own studies (Weiss, 1978) showed that, when examined on a curriculum-by-curriculum basis, no one curriculum was used in more than seven percent of the classrooms while most were being implemented in fewer than two percent of the classrooms. Summative results across all curriculum programs revealed that approximately one-third of all science teachers in grades 7-9 and slightly more than half of all grade 10-12 teachers reported "using" one of the many NSF programs in 1977. It should be noted that apparently no effort was made to determine what teachers meant by the word "using". In the light of what is known about change in education, it would be unreasonable to conclude that these programs were implemented in the way developers intended. No attempt was made to monitor and manage the implementation process. The "failure" of the curriculum reform movement of the 1960's was a failure to provide the resources and utilize the methodologies required to effect widespread implementation.

As Bybee has pointed out in Chapter 1, this is not the time for a belated return to the 1960s curriculum projects. If indeed they were adequate for the challenge of that time, they are not adequate for today's challenges. The thrust of this volume is that S/T/S themes constitute a responsive redirection of the goals of science education for the 1980s and beyond, and that, therefore, teachers must be prepared to teach toward S/T/S goals. The purpose of this chapter is to examine current knowledge about change, and in the light of the past 25 years, propose a plan of action to effect a redirection of science education toward S/T/S goals.

THE CHANGE PROCESS

Publications regarding change in science education have been rather limited. The Second Sourcebook for Science Supervisors (Eiss, 1976), contained two chapters with the word "change" in their titles. Eiss, in a chapter entitled, "Preparing for Implementing Change," began with a summary of McGregor's (1961) theory X and Y and proceeded directly to the conclusion that, "... theory Y offers the best environment for orderly change." (p. 83). He then used the tenets of McGregor to describe recommended actions by the science supervisor--clearly defined goals, trust, open communications, cooperation, consensus, positive leadership, effective outcomes and a satisfied constituency. Subsequently, he elaborated these into various functions, committees and aspects of the local change effort. He seemed to conclude that science supervisors need only to employ sound procedures in order to be successful managers of the change process. However, empirical evidence was not provided to support this conclusion. In the same volume, Butterfield (1976) examined the meaning of change and current science teaching practice. He suggested guidelines for successful "installation" of curriculum projects. While both of these chapters made apparently sound recommendations, they do not appear to be empirically based. Neither offers a theoretical model for understanding or interpreting the change process.

It may be helpful at this point to clarify the meaning of some terms and concepts that will be used frequently in this chapter. There appears to be confusion between the concepts of adoption and implementation. Adoption will be used here to indicate that part of the change process which includes the development, selection, and/or the decision making process up to the point that the innovation reaches the classroom. Implementation is used to describe the change process after that point. This would include strategies designed to monitor and support use by the staff. The term, change process will be used to describe the total change, including both adoption and implementation. Specific terminology within the change process includes innovation, intervention and institutionalization. Innovation will signify any new or "new-to-the-user" program. Intervention will be used to describe a category of actions which, by intent or accident, affect the implementation of the innovation. The condition of institutionalization will describe the final stage of implementation where the innovation is in place in classrooms throughout the school or district. It is the view of the authors that the schools have focused virtually all of their attention and resources on adoption and have failed to attend to the implementation part of the change process. As pointed out above, this is also the failure of national policy on change in science education though the NSF.

Empirical studies of change in education have also been limited. A Rand study by Berman, et al. (1975) examined the successes of several federally sponsored change agent projects. They found that innovations were rarely implemented as designed. Results indicated that there was: (1) mutual adaptation where both the innovation and the school were changed; (2) nonimplementation, where the school did not change and the innovation was ignored; or (3) co-optation occurred and the innovation was changed--usually drastically--to meet the needs of the school. Mutually adapted projects were reported to be more apt to be implemented and to persist.

Berman further noted that decisions to institutionalize an innovation at the school or classroom level after outside funding had ceased were related to: (1) whether it replaced existing programs; (2) its emphasis on teacher training; (3) the practical nature of that teacher training; and (4) whether the curriculum materials were developed by the project staff. Central administrative support for the program's continuance was related to the program's being viewed as inexpensive, congruent with the district's goals, having staff support and being reasonably "successful." While these results provide valuable insights and are data-based, broad insights into the change process are difficult to discern.

Models have proven helpful in decision making processes in that they provide a theory base for understanding the relationships among various components. In educational change it is important that models enable managers of change to make valid predictions concerning interactions and their outcomes in the change process. The educational change literature describes two models which appear to be helpful in moving science education toward an S/T/S focus. They are: Organizational Development (OD) (Owens, 1981) and The Concerns Based Adoption Model (CBAM) (Hall, Wallace, and Dossett, 1973).

OD concentrates on the modification of organizational structures and the resultant impact on the behavior of individual staff members, relying on behavioral goals as a key factor. It intends to enhance the capabilities of group members in order to provide institutions with a continually responsive and adaptive character. OD involves a team approach in which each member is encouraged to think, participate and become fully involved in the examination of how a particular problem affects the organization. Under the guidance of a change agent, (usually from outside the organization(s)) a specific strategy is evolved (with the continuing support of higher level administrators) to respond to a problem such as program adoption and implementation. There is recognition that the complex interchange of people and ideas is a powerful and effective resource when directed toward system environmental response and adjustment. OD is a systems approach intended to effect organizational renewal as opposed to a temporary solution. It seeks to provide an organization with knowledge, flexibility and specifically targeted planning and adaptive logistics.

OD recognizes that the potential contributions of people are often subsumed and/or fragmented through organizational beliefs, attitudes and values. Each interacting behavior and social force produces a state of fluid equilibrium. When stresses affect this balance the responsive and adaptive characteristics of the group are underused or seriously inhibited.

Organizational Development relies heavily on self learning through an experiential climate in which participants are encouraged to assess where they are and where they wish to be. Much of the OD approach is designed to encourage inquiry and open-minded experimentation by fostering a social climate that transcends traditional organizational frameworks. Creative thinking is encouraged and rewarded.

In the context of change in science education, OD could provide a frame of reference and forum in which "organizations" of science educators would be encouraged to discover, adapt, respond and plan for S/T/S. We could begin by asking questions utilizing the OD processes. What are the organizations or groups which may inhibit or contribute to the implementation of S/T/S? What are their unique perspectives? What are the behavioral and social barriers to the adoption of S/T/S? Can our collective wisdom evolve a specific implementation strategy for S/T/S? Is it possible to create a climate of acceptance among diverse points of view within the community for science educators in order to negotiate an S/T/S implementation plan?

Elaboration of answers to these questions is beyond the scope of this chapter, however, they represent critical issues which must be addressed and resolved if S/T/S is to become a reality in K-12 science. Others have raised these and other issues in even greater detail elsewhere in this volume. Historically, neither good ideas nor sincere efforts have been sufficient to sustain a major redirection of science education. A systems approach, such as OD, directs our thinking toward the perspectives of groups and individuals, and suggests a strategy for unifying science educators toward the S/T/S thrust. The broad problem solving approach to S/T/S implementation suggested by the OD framework shows promise in generating a consensus within the science education community. However, there is a need for defined strategies for accomplishing implementation at the local and national levels. The Concerns Based Adoption Model provides those strategies.

More than a decade of research and study of change at the Research and Development Center for Teacher Education at the University of Texas at Austin, has lead to the CBAM. This empirically-based conceptual framework (Hall, Wallace and Dossett, 1973) focuses on the individual teacher's experience as she/he moves through the process of adoption and implementation. Four assumptions are recognized as basic to the CBAM. They are:

1. Change is a process, not an event. It does not occur just because a law is passed, a regulation is formulated, or a purchase order has been sent.

2. Change is accomplished by individuals first, then institutions. The teacher is the real unit of change, therefore a focus on individuals is appropriate in understanding the change process.

3. Change is a highly personal experience. The individual experiences of most educators reinforce this assumption.

4. Change entails developmental growth in both feelings and skills in using new programs. The developmental growth in feelings provides the basis for the concerns for one dimension of the CBAM.

The work of the CBAM staff on monitoring innovations lead them to conclude that complex innovations can be expected to take from three to five years to implement. Considering the five to seven year textbook adoption cycle, it can be seen that by the time most teachers have the innovation (such as a new textbook) in place in their classroom, a new one is adopted.

The CBAM uses the term *concerns* to describe the feelings, attitudes, thoughts, ideas, or reactions the individual may experience in the change process. This construct was first described by Frances Fuller (1969) as she observed the growth of concerns among preservice teachers as they moved into and through their student teaching experience. Fuller concluded that this growth was developmental in nature and began with *self* concerns, moved to *task* concerns, and culminated in *impact* concerns. Hall and others used her work as the basis for their Seven Stages of Concern about the Innovation (Hall, Wallace and Dossett, 1973). The Seven Stages of Concern About the Innovation are presented in Figure 1. Subsequent work lead to the development of strategies for assessing concerns, one of which was a Likert-type questionnaire with five items in each of the seven categories. Individual scores are compared to a large norm group, converted to percentile scores and plotted on a graph of percentile ranks for each subscale, similar to Figure 2. The graph presents hypothetical data for each of four users: a non-user, an inexperienced user, an experienced user and a renewing user. These idealized data result in curves which concerns theory would predict for these user categories. The wave motion depicted in Figure 2 describes the developmental nature of the growth patterns of concerns. Curves for actual data rarely conform exactly to these curves, in part because real conditions are rarely ideal. However, the degree of agreement is significant and these idealized curves are helpful in interpreting real data.

The value of concerns data lies in its potential for directing interventions toward improving implementation. For example, the discovery that teachers have intense informational concerns should direct the manager to provide information about the innovation, whereas, giving such teachers a lecture on the impact of the innovation on students can best be saved until teacher concerns intensify on the consequences of using the innovation. Hall (1979) recommends certain interventions in response to the most intense concerns for every stage. The developmental nature of concerns suggests that lower stage concerns must be resolved before the higher stages of concerns will intensify. As concerns are monitored, the most intense concerns are targeted for intervention with the expectation that as they are resolved, higher stage concerns will subsequently develop.

A second dimension of the CBAM is Levels of Use (LoU) (Hall, Loucks, Rutherford and Newlove, 1975) which examines the teacher's behaviors and performance. The eight levels of teacher behavior or performance are presented in Figure 3. Comprehension of Levels of Use is facilitated by grouping levels. For example Levels 0, I and II are the "non-use" categories. They represent a spectrum from no action, through preparation to use of the innovation. Levels III and above are for users of the innovation and can be distinguished from each other in terms of the kinds of changes being made by users (teachers). Level IIIs are the making of changes dominated by user (teacher) needs, while Level IVAs are not making any changes in the new program. Levels IVB, V and IV are making "refinement" changes. "Refinement" is used here to describe changes intended to improve student outcomes.

Managers of an innovation could use LoU to monitor this spectrum of teacher behaviors (LoU 0 to 6). For example, the determination that the

STAGES OF CONCERN ABOUT THE INNOVATION*

6 REFOCUSING: The focus is on exploration of more universal benefits from the innovation, including the possibility of major changes or replacement with a more powerful alternative. Individual has definite ideas about alternatives to the proposed or existing form of the innovation.

5 COLLABORATION: The focus is on coordination and cooperation with others regarding use of the innovation.

4 CONSEQUENCE: Attention focuses on impact of the innovation on student in his/her immediate sphere of influence. The focus is on relevance of the innovation for students, evaluation of student outcomes, including performance and competencies, and changes needed to increase student outcomes.

3 MANAGEMENT: Attention is focused on the processes and tasks of using the innovation and the best use of information and resources. Issues related to efficiency, organizing, managing, scheduling, and time demands are utmost.

2 PERSONAL: Individual is uncertain about the demands of the innovation, his/her inadequacy to meet those demands, and his/her role with the innovation. This includes analysis of his/her role in relation to the reward structure of the organization, decision making, and consideration of potential conflicts with existing structures or personal commitment. Financial or status implications of the program for self and colleagues may also be reflected.

1 INFORMATIONAL: A general awareness of the innovation and interest in learning more detail about it is indicated. The person seems to be unworried about himself/herself in relation to the innovation. She/he is interested in substantive aspects of the innovation in a selfless manner such as general characteristics, effects, and requirements for use.

0 AWARENESS: Little concern about or involvement with the innovation is indicated.

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* Original concept from G. E. Hall, R. C. Wallace Jr., and W. A. Dossett, A Developmental Conceptualization of the Adoption Process within Educational Institutions (Austin, Texas Research and Development Center for Teacher Education, The University of Texas, 1973).

Figure 1

Hypothesized Development of Stages of Concern

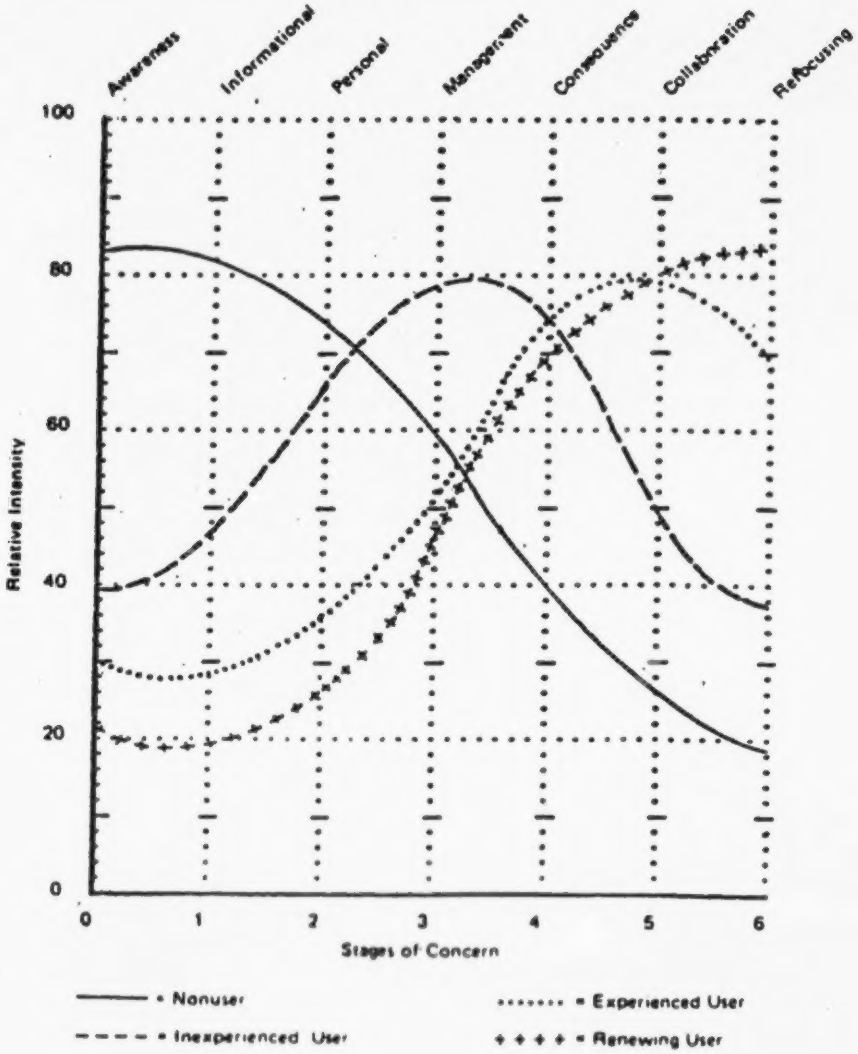

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Figure 2

LEVELS OF USE OF THE INNOVATION:

TYPICAL BEHAVIORS

	LEVEL OF USE		BEHAVIORAL INDICES OF LEVEL
USER	VI	RENEWAL	THE USER IS SEEKING MORE EFFECTIVE ALTERNATIVES TO THE ESTABLISHED USE OF THE INNOVATION.
	V	INTEGRATION	THE USER IS MAKING DELIBERATE EFFORTS TO COORDINATE WITH OTHERS IN USING THE INNOVATION.
	IVB	REFINEMENT	THE USER IS MAKING CHANGES TO INCREASE OUTCOMES.
	IVA	ROUTINE	THE USER IS MAKING FEW OR NO CHANGES AND HAS AN ESTABLISHED PATTERN OF USE.
	III	MECHANICAL USE	THE USER IS MAKING CHANGES TO BETTER ORGANIZE USE OF THE INNOVATION.
NONUSER	II	PREPARATION	THE INDIVIDUAL IS PREPARING TO USE THE INNOVATION.
	I	ORIENTATION	THE INDIVIDUAL IS SEEKING INFORMATION ABOUT THE INNOVATION.
	0	NONUSE	NO ACTION IS BEING TAKEN WITH RESPECT TO THE INNOVATION.

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Figure 3

Managers of an innovation could use LoU to monitor this spectrum of teacher behaviors (LoU 0 to 6). For example, the determination that the teachers were at LoU III (mechanical use) suggests interventions related to management of the innovation. Managers who use LoU are often suprised that frequently twenty-five percent or more of the teachers are non-users. LoU can help to confirm what most teachers know already, that among teachers supposedly using a given innovation, many simply are not using the innovation. Ascertaining LoU data requires the use of a focused interview (Loucks, Newlove and Hall, 1975) in the hands of a trained interviewer.

The third dimension of the CBAM, Innovation Configuration (IC) provides a descriptive picture of the innovation in terms of how its parts are being operationalized in the classroom. An innovation is frequently adapted or "drastically mutated" by the implementing teachers. Thus, in examining the nature of the innovation as it is being used, one would expect to find altered forms of the program.

In developing the IC, the innovation is examined to determine its major components. Components usually include materials, teacher role and student activities. Note that in the example included in Figure 4, these are listed at the left margin. Each component is subsequently described in terms of its "ideal," "acceptable" and "not-acceptable" variations of use. "Ideal" use, reflects the kind of use the developer intended. Subsequently, other variation are hypothesized for each component. The IC can be developed as a two-way matrix of components versus variations. As a cross-check, classroom observations and interviews are included in the process of developing the IC. The goal is to develop a two-way matrix of components versus variations which would include all combinations of component variations one might observe in any classroom where the innovation was being used. The combination of component variations used in a particular classroom is said to be the configuration of use in that classroom. The "acceptable" and "not acceptable" variations are sometimes referred to as the non-ideal variations and usually include a "not using" variation. Numerous ICs have been developed, but since the IC is innovation specific, it will generally be necessary to develop an IC for each innovation to be studied. No S/T/S IC is known to the authors at this time.

The CBAM is an implementation management tool. SoC, LoU and IC include measurement techniques which can be used to provide data about local implementation. These data could then be interpreted in the light of CBAM theory, making possible data-based decisions concerning appropriate interventions. Additionally, CBAM can be used as a monitoring tool within an implementation plan. One such use might involve the delineation of target goals, stated in terms of CBAM-referenced implementation characteristics, to be achieved at a point in time. For example, a school district might state a goal that thirty percent of the teachers will be at LoU IVA (routine use) by the end of the second year of implementation. Thus the criterion (target) is clear, and the method of monitoring it is specific.

Learning With Art
Configuration Checklist

	1	2	3	4
***1. Use of Lesson Packets**	Teachers and docents use lessons with visual aids whenever appropriate	Uses lessons with visual aids infrequently	Uses lessons without visual aids	Doesn't use lesson packets
***2. Community Artist Demonstrations**	Artists demonstrate and discuss with class whenever appropriate	Artists demonstrate without discussion with students	Artists demonstrate infrequently	Artists never demonstrate
***3. Artist Exhibitions**	Art is exhibited and discussed with students whenever appropriate	Art is exhibited but no discussion occurs	Art is rarely exhibited	Art is never exhibited
4. Visits to Museum	Students are taken to museum and discussion follows related to social studies units	Students are taken to museum with no follow-up discussions	Students are rarely taken to museums	Students are never taken to museums

— — To left of slashed line is ideal variation

—— To left of solid line is acceptable variation

* Critical Components

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Figure 4

RECOMMENDATIONS: A RESPONSIVE REDIRECTION

The application of ideas about change to the implementation of S/T/S themes in science education is not simple and straightforward. In accomplishing this task, it seemed best to establish the domains of change that appear to be involved in implementing S/T/S. Those domains are hypothesized to be: the goals of science teaching, the current practices of inservice science teachers, the preparation programs of preservice and inservice science teachers, the availability of high quality curriculum materials and curriculum development models, and the focus on implementation of S/T/S.

1. The goals of science teaching. S/T/S is important to our society and therefore should be a part of science education. Bybee makes this clear in chapter one. Some progress has already been made in specifying new goals as is suggested in numerous publications in the science education literature. NSTA's 1984 Yearbook (Bybee, 1984) provides extensive support for S/T/S, but goal delineation alone is not enough. Goals must become the policy statements which guide decision making. Some states have begun to require S/T/S in their curriculum documents as indicated by Spector, and as Penick has reported several local programs already reflect these goals. However, it must be recognized that S/T/S goals are antithetical to the suggestion that "more is better" and that its academic goals are the only goals of science. Therefore, it is recommended that a major national effort be mounted to develop consensus that the goals of science education should be redirected toward S/T/S.

2. Current practices of science teachers. Gallagher makes it clear that current practices of teachers in the field are inconsistent with S/T/S goals. S/T/S goals will not be promulgated on the crest of a wave of worksheets and irrelevant media, by teachers distracted from the tasks of effective teaching, or by using encyclopedic approaches to science content. What will be needed will be the ability to prepare students to cope effectively in a society in which science and technology impinge ever more personally on their lives. Problem identification and problem resolution skills will be central to the effort. Many science teachers are already practicing strategies that are consistent with S/T/S goals. The identification of these S/T/S teachers could provide role models for others to follow. However, we must not be deceived that identification and exposure to appropriate role models constitutes a solution to the problem of changing teacher practices. Current research on expertise and its transfer suggest that this is not the case. Not every one can do what the experts do. Therefore, it is recommended that the role(s) of S/T/S teachers be carefully defined as a component of the S/T/S innovation and that the competencies which comprise this role be identified. Such definitions would be a part of the Innovation Configuration which could be developed for S/T/S. Such an IC would be a valuable monitoring device, and would suggest interventions aimed at institutionalizing S/T/S teacher role(s).

3. *Inservice preparation programs*. The implementation of S/T/S cannot wait for the current group of practicing science teachers to retire. Programs must be designed and delivered that will assure that today's teachers are ready and able to implement S/T/S programs. Spector's chapter provides a rich resource of ideas on which such programs can be built. Therefore it is recommended *that graduate and inservice programs must provide science teachers with the background in methods and concepts to enable them to implement S/T/S in their classrooms*.

4. *Preservice teacher education programs*. The changing of higher education has been likened in difficulty to rearranging a graveyard! The forces and vested interests represented on the college or university campus are powerful, entrenched and conservative--apt not to change. This volume makes several suggestions which should strengthen the hand of the science educator as she/he moves the local undergraduate program toward S/T/S. Kuerbis presents an excellent rationale for the effort in Chapter 4. Duschl points out the central role of the history of science. Yager's chapter recommends a revolutionary new science teacher preparation program while Aikenhead's chapter suggests modifying undergraduate programs via a single course. Therefore it is recommended that *the modification of undergraduate programs should begin with a careful identification of the competencies new teachers will need to implement S/T/S learning experiences in the classrooms. Certification should be tied to the student's ability to demonstrate those competencies*.

5. *Teacher access to S/T/S curricula and/or curriculum development. Penick's chapter provides an initial resource of available* materials. Ellis's work reviews the development process for those who will want to "make their own." It must not be assumed that teachers are aware of or able to use curriculum development models. The CBAM can provide helpful insights into how teachers react to and use curricula. Careful attention should be paid to the change process as curricula are developed/adapted/adopted. Therefore it is recommended that *school science staffs must be trained in the curriculum development, selection, or modification process. Local curriculum components must be carefully specified, including the appropriate roles for the teachers and students. An IC will be helpful in defining the curriculum and in specifying how it is to be used*.

6. *Implementation of S/T/S curriculum*. The failure of the 1960's curricula to be widely implemented, suggests that we dare not rely on the development or selection process to produce a redirection of science education. Current knowledge about the change process should be brought to bear on this problem. Therefore it is recommended that *school districts and schools should develop a projected implementation plan which delineates implementation goals in terms of the dimensions of the CBAM. Stages of Concern and*

Innovation Configuration data should be collected and used to manage the implementation process.

7. Developing a broad consensus of support for S/T/S. The role of the various professional groups in science, science education, and education, should be assessed and planned in the S/T/S change process. Since science teachers frequently display respect for the opinions of the professional scientist, much could be made of statements of support by such individuals and organizations if they were widely circulated. State and national accrediting agencies must not be overlooked. If their standards already promote S/T/S, this should be publicized. Where they do not, work should be begun to modify those standards accordingly. State certification programs and science curriculum documents must reflect S/T/S themes and S/T/S teacher competencies. The knowledge, skill and role of school administrative and supervisory personnel must be updated to provide for the incorporation of S/T/S in school programs. Therefore, it is recommended that an all out effort be made to appeal to and gather support from all agencies, organizations, and school personnel who may have impact on the successful implementation of S/T/S. The magnitude of such an effort would require the participation and support of the NSF. This might be accomplished through a series of high level conferences of leaders of the various groups across the country. Further, NSF should play a major role in supporting the development of proven and transportable models for the various dimensions of the national redirection of science education toward the S/T/S theme.

It is encouraging that science educators find themselves in a period of self renewal. As we contemplate the dynamically fragile equilibrium within the triad of science, technology and society, OD encourages science education to recognize and internalize the strength of adaptability. The creation and implementation of an S/T/S frame of reference in this country through the education of its citizens is a monumental task. Upon reflection, one is tempted to dismiss the enormity of the undertaking as impractical. Yet, the S/T/S movement personifies the science educator's new state of consciousness and concern for the well being of citizens of the USA and the world. It challenges the authoritarian dominance of the idea that science is facts and concepts and the artificial position that the content should be compartmentalized into virtually unrelated parts. S/T/S will prepare citizens to evaluate scientific and technological enterprises by addressing the human factors involved in an S/T/S frame of reference, will apprise learners of the occasional fallibility of science as well as its frequent triumphs. Moreover, such learners would be expected to grasp the complexities of the issues which confront our society and demonstrate skill in selecting and implementing various problem resolution techniques.

Achieving this dramatic reorientation of science education is a herculean task that will not simply arrive quietly on our doorstep. A consensus of purpose is required which will likely require the kind of responsive adaptation that utilizes the best of human creativity, responsibility, and commitment. As Yager says, "The task is enormous, the responsibility is awesome, but can we afford anything less?" The discovery of new information and hence the application of new technologies with their attendant impacts on humankind accelerates on a minute-by-minute basis. Yet, today's science programs rarely include any science content that has been discovered since 1900 or the technologies this new science has spawned. As Hickman points out in Chapter 8, science is changing both in its rate of growth and in its essential character. The physics of Newton was once believed to explain all conceivable properties of motion. A perspective of the 21st century must be brought into the classroom since today's adolescents will be just beginning their most productive years by the year 2000. That is 15 years away. What will we be teaching that will be useful to them then, or in 2035 when they are age 65?

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